THE BOOK WAS DRENCHED

INDIA METEOROLOGICAL DEPARTMENT

WINDS, WEATHER AND CURRENTS

ON THE COASTS OF INDIA

AND

THE LAWS OF STORMS

SECOND EDITION

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PREFACE TO SECOND EDITION

After the amendment in 1928 by the Government of India of the rules for examination of candidates for certificates of competency as Masters and Mates of Steamships, the need was felt of a text-book to enable Indian seamen to study the laws of storms and the prevailing winds, weather and currents in Indian Waters. To meet this need the preparation of this pamphlet on " Winds, Weather and Currents on the Coasts of India and the Laws of Storms " was undertaken by the India Meteorological Department. The first edition of the pamphlet was compiled by Mr. S. Basu in the Marine Section of the Poona Meteorological Office from sources of information available in the department. It has now been revised with alterations and additions. The chapter on Currents and Tides has been re-written. The following are the main additions :—

(1) A short preliminary chapter on Wind and Pressure;
(2) Tables of climatological data of 14 coastal stations : and
(3) A glossary of important meteorological terms occurring in the pamphlet.

The attention of seamen is invited to the following two publications of the India Meteorological Department :—

(1) Weather Codes for Ships in Indian Waters,
Part 1—Weather Reports from Ships (1936) ; and
Part 2—Weather Broadcasts to Ships (1939).
(2) Code of Storm Warning Signals for use at Indian Maritime Ports (1936).

The India Meteorological Department will welcome suggestions for increasing the usefulness of this publication in future editions.

C. W. B. NORMAND,
Director General of Observatories.

POONA,
July, 1941.

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CHAPTER I

WIND AND PRESSURE

Wind

Wind is air in movement. To specify a wind, one must mention both its direction and speed. The direction of a wind is taken to be that from which it blows and is usually given in 8, 16 or 32 points of the compass. When the wind direction is given as NNW, it means that the wind is coming from the northnorthwest and when it is given as N/W, the meaning is that the wind blows from between N and NNW. The speed of a wind is expressed in miles per hour, or among sailors, in knots.

1 knot=1·152 miles per hour.

Wind Force and its estimate.—Beaufort scale.— Before the days of instrumental meteorology, the speed of wind was estimated by its effects. In 1805, Admiral Beaufort of the British Navy devised a scale of wind force which is still used widely both at sea and on land. The scale has 13 figures, 0 to 12, and the higher the figure, the greater is the corresponding wind speed. The Beaufort scale of wind force, the mode of estimating it on sea and land and the corresponding wind speeds are given in *Table I.*

The steamship mariner of to-day estimates the force of wind at sea by its effect on the surface of the sea. In a calm, the sea-surface is glassy, with a light wind it is smooth but with small wavelets, with a moderate gale it becomes rough, and with a strong gale blowing, the sea becomes very high. The state of the sea surface corresponding to different wind forces is given in the sixth column of *Table I.*

TABLE I

Beaufort Scale of Wind Force

Beaufort Number.	Brief description of wind.	Limits of speed in miles per hour.	Specification of Beaufort Scale.			Approximate Equivalent Sea Disturbance Scale in Open Sea.	
			For use inland.	For use on coast.	Corresponding state of open sea.	Code Figure.	Probable Mean Height of Waves in ft.
0	Calm	0—1	Smoke rises vertically ..	Calm	Calm; glassy	0	..
1	Light air ..	2—3	Wind direction shown by smoke drift but not by wind vanes.	Fishing smack just has steerage way.	Calm; ripples without foam crests.	1	½
2	Light breeze	4—7	Wind felt on face, leaves rustle; ordinary vane moved by wind.	Wind fills the sails of smacks which then move at 1-2 m.p.h.	Smooth; with small wavelets.	2	1
3	Gentle breeze ..	8—11	Leaves and small twigs in constant motion; wind extends light flag.	Smacks travel at 3-4 m.p.h.	Smooth; crests of wavelets begin to break.	2	2½
4	Moderate breeze ..	12—16	Raises dust and loose paper; small branches are moved.	Good working breeze; smacks carry all canvas with good list.	Slight; with white horses	3	5
5	Fresh breeze .	17—21	Small trees in leaf begin to sway	Smacks shorten sail ..	Moderate; many white horses.	4	9
6	Strong breeze	22—27	Large branches in motion; whistling in telegraph wires.	Smacks have double reef in main sail.	Rough; large waves begin to form; extensive white foam crests.	5	14
7	Moderate gale .	28—33	Whole trees in motion ..	Smacks at sea lie to ..	Very rough; white foam from waves begins to be blown in streaks along wind.	6	19
8	Fresh gale ..	34—40	Breaks twigs off trees; generally impedes progress.	All smacks make for harbour.	High; edges of crests break into spindrift; well marked streaks of foam along wind.	7	25
	Strong gale ..	41—48	Slight structural damage occurs.	....	Very high; long overhanging crests of waves; heavy rolling of sea; Visibility affected.	8	31
10	Whole gale .	49—56	Trees uprooted, considerable structural damage.				
11	Storm	57—65	Widespread damage ..	. ..	Exceptionally high: small and medium sized ships lost for a time to view behind waves; Sea completely covered with white foam.	..	37
12	Hurricane .	65	....	....	Phenomenal; sea white with driving spray. Visibility very seriously affected.	9	45 or more.

Pressure

Wind is caused by differences of atmospheric pressure at the same level. The pressure at any place is the weight of the atmosphere on a unit of area and is equal to the weight of a column of mercury of unit area of cross-section and height equal to the height of mercury in a barometric tube. If the pressure is measured at a number of places at sea level and plotted on a map, we can draw a series of lines, each passing through points having the same pressure. These lines are called *isobars*. Isobars are generally drawn with constant difference of pressure. Thus we can have isobars corresponding to 29·85, 29·90, 29·95, 30·0, etc., inches of pressure. If some of the places at which the barometers are read are not at sea level, their readings should, before plotting, be reduced to what they would be at sea level. Similarly if the mercury in the different barometers is at different temperatures, the readings of the barometers should be reduced to the same standard temperature. A correction is also required for the variation of gravity with latitude.

If a number of isobars on a map enclose an area of low pressure, the region of lowest pressure is called a *barometric low* or *depression* or cyclonic storm depending on the strength of the winds, and if they enclose an area of high pressure, the region of highest pressure is called a *barometric high* or anticyclone. If we examine a series of maps showing isobars and winds, it is found that there are certain simple rules governing the relation between them.

(1) The winds are strongest where isobars are closest and *vice versa*. The rate at which pressure decreases in a direction at right angles to the isobars is called the barometric gradient. In the same latitude the greater the barometric gradient, the greater is the speed of wind.

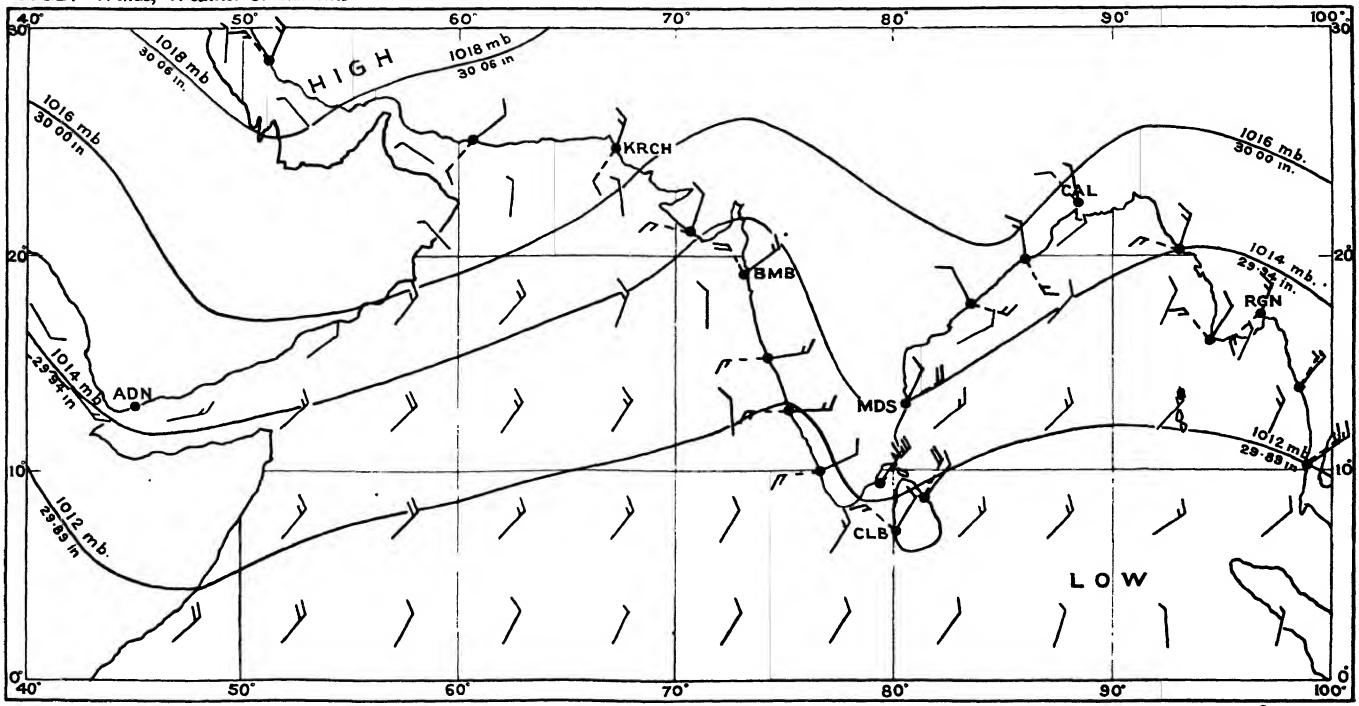
(2) The wind blows roughly parallel to the isobars, but with a definite tendency to flow from the region of high pressure, into that of low pressure. The angle between isobars and wind is generally 10° to 30° at sea and 20° to 50° on land.

(3) When we face the wind the lowest barometer is towards the right hand side in the northern hemisphere, and towards the left in the southern. (Buys Ballot's Law.)

CHAPTER II

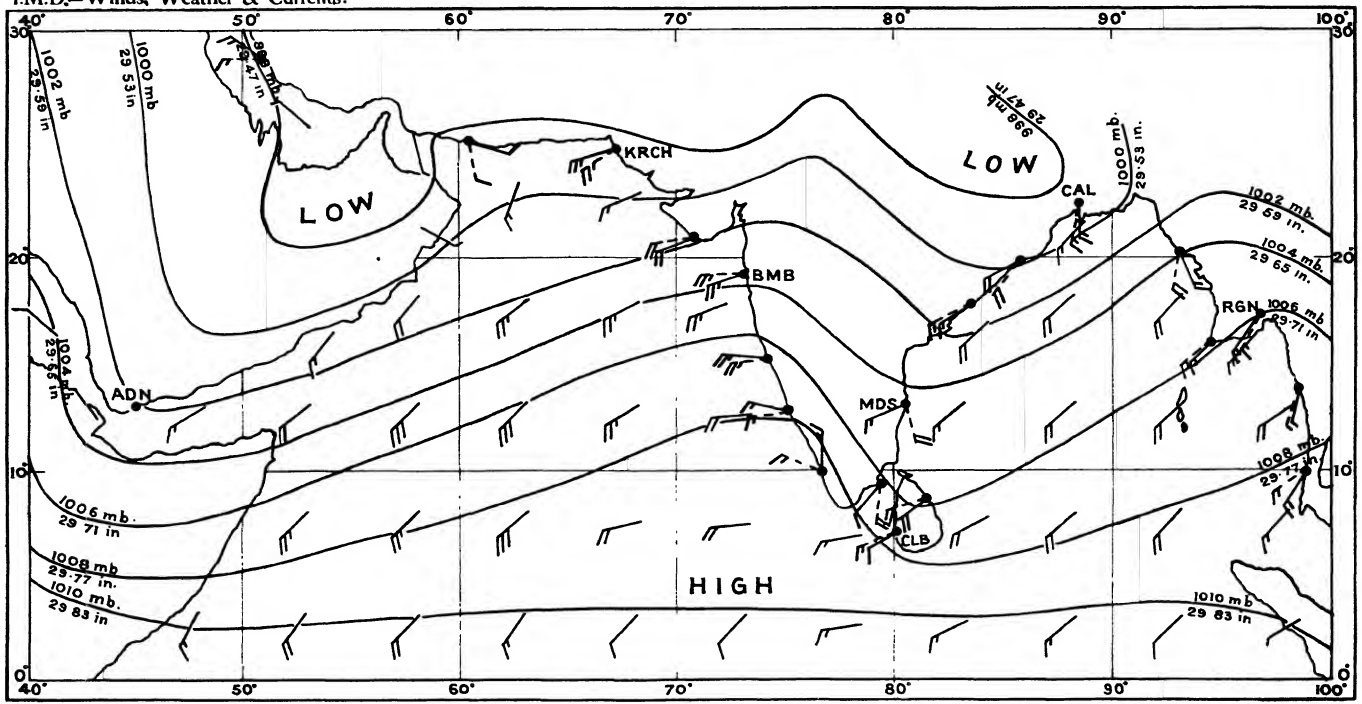
WIND SYSTEMS IN THE INDIAN SEAS—THE MONSOONS—SEA AND LAND BREEZES

Monsoons.—The outstanding feature of the wind system in the Indian Seas is a seasonal reversal of direction known as the " monsoons ". During the winter third of the year, December to March, the general flow of air is from Iran, India and Burma to the Arabian Sea and Bay of Bengal and thence towards the equator. Over the Indian Seas, the winds in this season have mainly a northeasterly direction, and are therefore called the *northeast monsoon* winds. January is the month in which this air movement is best seen. In the summer third of the year, June to September, the flow is almost completely reversed and the winds blow from the southwest over the sea towards India and Burma in the great current known as the *southwest monsoon*. July is a representative month of the southwest monsoon season. In illustration of the two monsoons, charts of winds and pressure for January and July are reproduced in *Figs. 1 and 2*. In January the seat of high pressure is in Central Asia and the pressure decreases steadily from the north of our area to the south. In July the region of lowest pressure is over northwest India and the high pressures in our chart are over the equatorial sea. This change between January and July is mainly caused by changes of temperature. In both charts, the region of lowest pressure is near the region of highest temperature and that of highest pressure near the region of lowest temperature. Air tends to flow from a region of high pressure to one of low pressure ; hence, looking at the January chart, we would expect winds to blow, roughly, from north to south, and on the July chart from south to north. Atmospheric motion, however, is not as simple as this. There is another important control. The rotation of the earth causes a current in the northern hemisphere always to curve towards the right hand side. A current trying to move from north to south, is deflected towards the right and becomes a northeast current as in the northeast monsoon. A current moving from south to north is also deflected towards the right



At the coastal stations both morning & afternoon winds are given. The latter are shown by discontinuous lines. *To face page 6.*

FIG. 1. PRESSURE AND WIND IN THE INDIAN SEAS IN JANUARY.



At the coastal stations both morning & afternoon winds are given. The latter are shown by discontinuous lines. G.P.I.S. POONA/1962

FIG. 2. PRESSURE AND WIND IN THE INDIAN SEAS IN JULY.

and thus becomes a southwest current as in the southwest monsoon. If there were no friction, the deflection of the current due to the earth's rotation would make it flow round the low pressure area along the lines of equal pressure. Mountain ranges and coast lines produce localised deflections of air currents.

The terms " southwest " and " northeast " applied to the two monsoons are truly descriptive of them only in the Bay of Bengal and the western half of the Arabian Sea.

Between the two main monsoon seasons are two transition periods, making in all four seasons, into which the year may be divided for the purpose of describing the prevailing winds in the Indian Seas. The four seasons are :—

(1) The Northeast Monsoon Season—(December to March) —when northeast winds of land origin prevail over the greater part of the Indian Seas :

(2) The Hot Weather Period—(April and May)—the transitional period of preparation for the southwest monsoon :

(3) The Southwest Monsoon Season—(June to September) —when southwest winds of oceanic origin blow steadily ; and

(4) The Transition Monsoon Period—(October and November)—when southwest winds of oceanic origin retreat southwards and are replaced by northerly winds of land origin.

Northeast Monsoon (December to March).—This is a season of winds of land origin and thus of clear or lightly clouded skies and little rain. Over the land this is the season of lightest winds. Air movement in northern and central India is from the west down the Gangetic plain. The stream-lines of airflow curve through northwest to north across Bengal and to northeast in the Bay of Bengal. Across the Indian Peninsula the air moves from the east and passes out into the Arabian Sea

where winds are light northerly near the Indian coast but become stronger and steadier further west, blowing from north-northeast or northeast. A feature of this period is the succession of cold weather storms, or winter depressions, which pass from the west through Iraq and Iran to northern India and cause considerable snowfall on the western Himalayas and rainfall in the neighbouring plains. These depressions sometimes give rise to squally weather in the north Arabian Sea and off the Bengal coast.

Hot weather period (April and May).—During this period temperature rises in central and northern India, the rise of temperature being accompanied by a fall of pressure. Winds become light in the centre and south of the Arabian Sea. Off the west coast of the Peninsula the winds strengthen and back to northwest, and off the east coast they become southerly to southwesterly. In middle and south Bay of Bengal the winds are variable and are sometimes interrupted by calms. It is a season in which severe tropical storms may develop in either of these seas (see later chapters) and in which some coastal districts are liable to be visited by thunderstorms or severe local storms, especially the Bengal coast, where the local storms known as "*Nor'westers*" or "*Kalbaisakhis*" are experienced.

Southwest Monsoon (June to September).—The summer monsoon is a season of winds of oceanic origin with high humidity and frequent and heavy rain over nearly the whole area. It sets in on the Travancore coast at the end of May or early in June and on the south Burma coast sometime in May. The monsoon invades India in two main currents. Within two or three weeks, it takes possession of the whole Bay of Bengal and the Arabian Sea up to their northern coasts. The current from the Arabian Sea blows on the west coast from directions between west and southwest and spreads over the Peninsula, Central Provinces and Gujarat. The Bay current sweeps from southwest over the Bay towards Burma. The southern portion is either forced across the Tennasserim hills or passes up the Irrawadi valley and the remaining portion advances up the Bay and is deflected by the Arakan hills and the Himalayas.

first towards the north across the Bengal coast, and then towards the northwest up the Gangetic plain. A number of cyclonic storms forms in this period at the head of the Bay of Bengal and, after crossing the Bengal or Orissa coasts, moves in a northwesterly direction over the Indian land regions. These are times of strong monsoon in both seas. At other times both branches of the monsoon may relax their strength for a spell and fair weather with moderate wind may prevail for days or even for weeks. In September, conditions rapidly change and the rain-bearing winds cease to penetrate to northwestern India.

The Retreating Monsoon (October and November).—The transition from the wet to the dry monsoon begins in the latter part of September and is usually not complete until the middle of December. It is thus a transitional period of considerable length and differs in this respect from the transitional period at the beginning of the southwest monsoon, which is usually established rapidly over the whole Indian area and extends over the greater part of India in the course of a fortnight or so. The advancing monsoon current is a vigorous movement; but the retreat or withdrawal is a much more gradual and intermittent process. Before the end of October, the southwest winds weaken and then disappear in the Arabian Sea off the west coast and in the centre of the Bay of Bengal, but they persist for some time in the extreme south of the Bay. In the meantime, northerly winds develop in the north of the Bay and extend as a northeast current towards the south Madras coast. The inter-play between these two currents gives rise to alternate periods of fine dry weather and boisterous wet weather. Each period of wet weather is, as a rule, associated with the development and progress of a cyclonic storm. This indeed is the most favourable season of the year for the formation of severe cyclones in the Bay of Bengal.

Sea and Land Breezes.—Besides the seasonal winds described above, there are local and seasonal winds along the coasts. The most important of these local winds are the sea and land breezes. By day, the air over the land near any coast

becomes, as a rule, warmer and therefore lighter than the air over the sea with its more equable temperature ; the heavier air from the sea flows in as a cool " *sea breeze* " displacing the warm lighter air over the land. At night, on the other hand, the land cools by radiation faster than the sea and so the air over the land becomes cooler and heavier than the air over the sea ; hence the heavier land air slides out over the sea as a " *land breeze* " and displaces the warm lighter air that rests over it. When these breezes are regular, the land breeze begins to weaken after about 9 hrs. in the morning and decreases to a calm about midday. Soon afterwards, the sea breeze sets in, increasing in strength as the evening advances. Some time after sunset, the sea breeze dies down and is followed by a calm which continues till the land breeze commences. The time of onset of the land breeze varies with the month and the place, but is generally after 22 hrs. At first the land breeze comes as a fluctuating gentle wind ; it soon becomes steady and continues so till 9 hrs. or 10 hrs. next morning.

Sea and land breezes are very pronounced along the Indian coasts during the bright sunny weather of the northeast monsoon season. They are least pronounced during the southwest monsoon when cloudy weather prevents the land from heating up by day or cooling by night, and when, in any case, the regular strong winds of the season overcome the daily land and sea reversal.

Sea and land breezes deserve attention from sailing vessels if they are to take advantage of them. In the morning and before noon, it is advisable to edge more out from the coast to get an offing of 15 or 20 miles and be ready for the sea breeze. In the evening it is desirable to be near the shore before the land breeze comes on ; if close in prior to the commencement of the land breeze, short tacks are made near the shore until the breeze comes off. With the land breeze during the night it is prudent to keep well in shore if the wind admit it without tacking, for it is stronger and steadier there than farther out.

CHAPTER III

LOCAL WINDS AND WEATHER ON THE COASTS OF INDIA.

In this chapter, a brief description is given of the winds and weather prevailing in each season in the different coastal zones of India and Burma from Gwador on the Mekran Coast to Victoria Point in S. Tenasserim. The coastal strips occurring in the following descriptions are marked on the map shown in *Fig. 21.*

Mekran Coast (Long. 60° E to 67° E).— From October to February, land and sea breezes prevail. They begin to weaken in March and merge into the general wind circulation in April; the predominant winds during these two months are light to moderate from west or southwest. May is the most windy month on the eastern half of this coast where moderate to strong west to southwesterly winds are met with, while in the western half, the winds are light and variable. The weather is generally fine and the sea smooth throughout the months October to May, except when affected by cyclonic storms in the Arabian Sea or by western disturbances. Cyclonic storms in the Arabian Sea moving northwestwards affect the coast at rare intervals in the beginning and end of this period, *i.e.*, in October and November, and in May. They cause cloudy and, thundery weather with gales, rainsqualls and rough seas. During the winter months, December, January and February, gales or squalls with rough seas and heavy swells are sometimes experienced in association with the eastward passage of winter depressions over Baluchistan. The squalls behind these winter depressions may raise clouds of dust and produce a dust-storm or thick dust haze; they are often the precursors of strong cold northwesterly winds known as "*Shamals*".

The dust haze may sometimes persist for a few days after the strong winds associated with the dust storms have subsided.

A period of threatening weather, which may sometimes be associated with the northwestward movement of a cyclonic storm in the Arabian Sea in early June, is usually followed later in the month by a moderate monsoon gale from westsouthwest which lasts from a few days to a fortnight and is preceded or accompanied by a heavy swell and rough sea. A westsouthwest monsoon breeze and swell (southerly to easterly winds

over the western half of the coast) continue throughout July. The wind and swell diminish in August, when small crafts go out to sea again, and by the beginning of September the monsoon is generally at an end. Between mid-July and September, depressions move westwards over northern India and occasionally reach the north Arabian Sea when they may cause rain squalls and thunderstorms on the Mekran coast with moderate to rough seas.

Visibility.—The early part of mornings, from an hour before to an hour after sunrise, the atmosphere remains foggy or misty in March, and towards the latter half of the month dust begins to be blown about during the day causing loss of visibility. In April, the air sometimes remains hazy following dust storms. Visibility is decidedly poor along this coast in May on account of dust haze everywhere and, in addition, occasional morning fog in the eastern parts of the coast. The poor visibility due to dust continues in June. In July the atmosphere begins to clear, though along the coast misty and hazy conditions may prevail in the early morning. The visibility remains generally good thereafter, except for occasional morning fog in October and November.

Sind and Kathiawar Coast (Karachi to Gulf of Cambay).—Weather is generally fine and seas smooth in the cold weather months; occasionally, however, local gales and squalls occur in association with the eastward passage of western depressions from Iran to northwest India. The characteristic cold weather months are December and January, when moderate morning land breezes generally alternate with weak afternoon sea breezes; the land breeze is the predominating feature and at times blows continuously for two days or more on end. After calm nights in the cold weather banks of fog may be seen on this coast at early dawn, which drift out to sea with the land breezes. Mirages are of frequent occurrence. From February onwards the westerly and south-westerly sea breezes become gradually more pronounced in the afternoons, and from April onwards they blow by night as well as by day, being strongest in the afternoons. The south-west monsoon sets in June, attended with overcast skies,

showers and strong winds at times rising to a fresh gale. It remains vigorous throughout July and August and weakens rapidly in September. The rainy spells on this coast during the monsoon are generally associated with depressions which advance westwards from the Central Provinces or the Gangetic plain; winds on the coast are then variable in direction and the rain may be accompanied by thunderstorms. A heavy swell begins in the middle of May (when coasting steam vessels and small craft cease to put to sea) and continues with varying intensity until the end of the monsoon.

The Konkan and Kanara Coasts (Gulf of Cambay to south of Mangalore).—Throughout the cold weather period the wind blows on the average from some northerly direction, in October from northwest, in November, December and January from north and in February from northnorthwest. The daily land and sea breezes are well marked, the former blowing from the northeast in the mornings and the latter from the northwest in the afternoons and evenings. From March to May the average wind direction backs from northwest to westnorthwest and the land breezes become very uncertain, seldom coming off till morning; they continue for so short a time that they are of little advantage to sailing vessels. It is therefore necessary to keep an offing to be ready for the sea breeze, which in this season sets in at about noon. A feeble land breeze sometimes follows; but more frequently light airs from northward or calms may be expected from nearly midnight to about noon on the following day when the northwest sea wind again sets in. Sometimes these northwest winds are particularly strong, producing a short choppy sea and a drain of lee current; so that when it falls to a calm, it is necessary to anchor at times with a light anchor to avoid being driven southward.

The northwesterly winds continue, but are often variable and uncertain in May. The weather is cloudy with showers and lightning, which come at times from the southeast. In this month a gale from southwest may occur; and it is prudent therefore to keep well out from the land and be prepared for bad weather, in order to avoid being driven on a lee shore if a storm should set in from westward.

During the period of change before the southwest monsoon sets in, the small coasting vessels run in the afternoon into the nearest river or place of shelter south of Bombay; but large vessels should have sea-room.

At evening in May and in early June heavy clouds sometimes collect and hard squalls occur with rain at night. The southwest monsoon normally sets in at the end of the first week of June and up to the middle of August weather is generally very unsettled with hard squalls, much rain, dark cloudy weather and a heavy southwesterly swell. The monsoon begins to weaken in August and finishes in September. A period of light variable winds and frequent calms with cloudy weather and occasional showers intervenes. Late in October or early in November there is frequent thunder and lightning associated at times with a storm from southwards. After this period the northerly winds of the winter months are established.

Visibility.—During the season of northwest winds (February to May) the atmosphere is generally hazy southward of Bombay along the Konkan and Kanara coasts; this is particularly marked in March and April. Owing to the haze the land and trees along the coast appear to be at a much smaller distance than they really are.

During the period from April to October the Western Ghats are usually enveloped in a dense mist or haze, which hides the mountains from view. These mists, however, occasionally disperse for short intervals after heavy falls of rain. In October early morning fogs occur obscuring from the view the low-lands and projecting headlands up to about sunrise or a little later.

Malabar Coast (Lat.12½ N. to Cape Comorin).—The daily variation of morning land breeze and evening sea breeze is a marked feature of the winds on the Malabar coast during the northeast monsoon season. In October the wind is generally weak and mostly off the sea, the land breezes as yet being occasional, light and uncertain. The land breezes are strongest and most regular in December and January, but are also fairly well marked in November and February; even in these months the afternoon sea breeze remains a regular feature, despite the

opposing influence of the northeast monsoon winds in the upper air. From March onwards, the land breezes decrease in strength and duration and are not always regular. Thus the navigator may calculate on sea breezes for nearly all the year, but on regular land winds for only about four months.

Opposite gaps in the mountain chain, as at Palghat on the south of the Nilgiri hills, the land winds in December and January, being helped by the northeast monsoon, sometimes continue to blow for more than a day without any intervening sea breeze. This also occurs, but in a lesser degree, off Karwar where the valley of the Sadasivgad river assumes a straight funnel shape eastwards towards the interior of the Peninsula.

South of the Palghat gap the southwest monsoon sets in late in May. It frequently commences with a gale from southeast veering to south and southwest where it ultimately remains; at other times it commences with squalls from southwest, and a heavy long swell rolling in upon the shore. In June the wind keeps mostly between southwest and west by south, with much rain, high sea and severe squalls at times. In July the weather becomes a little more settled and the squalls veer sometimes to the west and westnorthwest. The sky is mostly obscured by heavy clouds during the southwest monsoon season, but considerable intervals of fine weather are occasionally experienced. In August the squalls veer pronouncedly to the west and westnorthwest and winds become northwesterly or westnorthwesterly.

In September the weather moderates. West and westnorthwest winds are the most prevalent while calms are experienced off Cape Comorin. Severe squalls are rare although the weather is often cloudy and threatening with heavy showers. A swell often rolls in from westsouthwest in this month, particularly during unsettled, squally weather. After some weeks of mostly fine weather but with frequent showers, the Malabar coast is usually visited, in the end of September or the beginning of October, by strong easterly squalls, rain and thunder which finally close the southwest monsoon season.

The navigation southwards along the west coast of India, for sailing vessels, during October and a great part of November,

is usually tedious and uncertain; for there is no dependence on the winds till late in November. But the light winds are not unfavourable for sailing down the coast as the drain of the current is still generally to the southwards.

Gulf of Manar (Cape Comorin to Pt. Calimere and the west coast of Ceylon).—On the west coast of Ceylon, land and sea breezes occur from December to March (*i.e.*, the northeast monsoon season) and the weather is generally fine, but the winds along the Indian shore of the gulf do not assume the character of land and sea breezes until February. The sea breezes gradually become of longer duration after February and increase in force till about the middle of May.

Towards the end of April, at night the wind becomes light and variable and squalls and showers of rain may occur while a swell is experienced from the west. The sky becomes overcast in May, banks of clouds rise over the ocean and winds begin to blow continuously from the southwest. The southwest monsoon gains strength in June, and the fishermen seldom go out to sea in this month. Showers become less frequent in July, but the weather is cloudy and hazy with generally a fresh breeze; the wind moderates near the head of the gulf in the mornings and blows strong again in the afternoons. Fresh southwesterly to westsouthwesterly winds continue in August and September but the weather is generally fine, in the afternoon the breezes are strengthened and are accompanied with occasional squall and rain. The atmosphere often remains hazy in September.

October has more unsettled weather and at times there are heavy squalls with rain towards the end of the month. During November the winds are light and variable between northeast and westnorthwest; weather is very unsettled with frequent heavy squalls and rain. About the middle of the month the northeast monsoon is ushered in by lightning, thunder and heavy rain. The northeast monsoon lasts till the end of January and blows steadily from northnortheast along the Indian coast; but in the northwest part of Ceylon it is modified by land and sea breezes and is attended with generally fine weather except for occasional showers and hazy atmosphere.

The East Ceylon Coast.—Weather is almost invariably fine from February to April with occasional light squalls accompanied by thunder and lightning, at the end of this period. In May winds become southwesterly with cloudy skies and the southwest monsoon sets in towards the end of the month. The island of Ceylon shields the east coast from the full force of the southwest monsoon, but at some distance off the coast, as well as on the south coast, isolated rain squalls are of frequent occurrence. The monsoon weakens generally in September and October and the force of the southwesterly winds in these months is very variable ; the winds are feeble when fine weather prevails but invariably strengthen when squally or stormy weather prevails in the centre of the Bay of Bengal. After a period of light variable and unsteady winds the northeast monsoon sets in during November, and continues in strength until January ; November and December are the two rainiest months of the year on this coast.

Coromandel Coast (Pt. Calimere to Lat. 15° N.).—Weather is generally calm during the first half of October, but later, northerly to easterly winds set in and prevail till about the middle of February. Land and sea breezes are very weak throughout this period, being at their minimum in November. Rain is general over the southern part of the coast in November, which is the rainiest month and also the month when the coast is most liable to be affected by severe cyclonic storms which travel west or northwestwards from the south of the Bay of Bengal and cause spells of strong winds, severe rain-squalls and rough seas. The weather improves in December and is generally fine in January with much clearer sky and very little rain. Winds are less steady and strong in February when the normal direction at Madras is easterly. Hereafter land and sea breezes strengthen ; they increase rapidly in March and April and are most strongly in evidence during the period May to September except on those days on which the southwest monsoon is strong. The land wind blows in the morning hours after sunrise, the sea breeze commencing in the early afternoon hours. In March and April southeasterly winds predominate and become very strong during the day. They veer towards south as the season advances, sometimes blowing as "long-shore winds" directly or nearly directly from the south. The average wind direction in Madras is southwesterly in May, but it undergoes greater variations in direction and strength

during the twenty-four hours each day in this month than at any other period of the year; occasionally indeed, a westerly wind prevails in this month throughout the day so that the sea breeze which usually sets in about midday does not appear at all. Weather is generally fine during March to May interrupted occasionally by thunderstorms. Depressions sometimes form in the centre or south of the Bay, and during the first half of May they may move in a westerly direction towards the Madras Coast, and for a time establish weather similar to that of November. In June southwesterly winds prevail, but only occasional showers and rain squalls occur on this coast. On days when the southwest monsoon is strong, the sea breeze either does not set in on the Madras coast at all or lasts for a very short time. During July, August and September, the southwesterly wind becomes weaker and rain squalls become more and more frequent, and showers increase on the Madras coast. Sometimes very heavy and sudden showers of 2 to 4 inches are received in September, calms being frequent towards the end of the month.

The Circars Coast (Nellore to Gopalpore).—The dry season sets in by the end of November and lasts till early May. The mean winds are generally northeasterly during, November and December, veer round to east during January and become eastsoutheast to southsoutheasterly in February and first half of March. Land and sea breezes are well marked during the c ld weather months, December to February. There is a pronounced shift of the predominating winds by the end of March from southerly to southwesterly, the weather remaining fine throughout. In May and June cyclonic storms originating in the Bay of Bengal approach this coast and affect the weather; in May the storms generally curve northeastwards towards the head of the Bay but in June they mostly pass inland through the Orissa Ganjam coast. Steady southwesterly winds predominate during July to end of August which is the rainiest period on this coast. During the withdrawal of the southwest monsoon, in September, October and November, this coast continues to get rain and squally weather in association with cyclonic storms some of them being of severe intensity. These storms generally form in the central Bay of Bengal about Lat. 16°N. in September and further south in October and November and may strike the coast causing much damage to life and property. In October

the winds shift to a northerly direction and gradually the north-easterly winds of the cold season appear and hold steadily. By the end of October or early November the rain slackens and feeble land and sea breezes set in and gradually gain strength.

Orissa and Bengal Coasts (Gopalpore to Cox's Bazar).—In the middle of October the southwest monsoon winds are replaced by light unsteady northerly winds usually with some easting, calms being met with on the Chittagong coast. As the season advances these northerly winds increase in steadiness and speed, and in November and December blow as dry land winds from the northnorthwest to northwest, with the variation that they may be northeasterly winds in the mornings on the Chittagong coast. From the beginning of October to the middle of December, cyclonic storms occur at irregular intervals in the Bay and occasionally advance northwards, curving sometimes northeastwards towards the Chittagong coast. They are sometimes of excessive violence and a great majority of them affect the winds and weather on the Orissa-Bengal coast. Dry northerly land winds with fine weather prevail as a rule in January and the greater part of February except during the brief periods when cold weather depressions cross northeast India. Winds during these disturbances shift round to southerly directions, and the weather becomes cloudy with occasional squalls. On the Chittagong coast marked land and sea breezes prevail from the end of October to the middle of March.

There is a feeble indraught of local sea winds across the Bengal coast by early March. Those southerly winds gradually strengthen, are vigorous and steady in April and May and continue unchanged in general character until the first or second week of June being sometimes of exceptional strength. These sea winds advance chiefly into eastern and northern Bengal and into Assam across the Assam hills and give rise to frequent afternoon and evening thunderstorms and much rain in those areas. Similar storms of considerable intensity occur in west Bengal, but not so frequently as in east Bengal. They usually advance from the northwest, and hence they are known as "*Nor'westers*". They occasionally pass seawards across the Bengal or Orissa coasts, during April, May and June and may be felt up to distances of 70—80 miles from land.

The following is a brief description of a typical Nor'wester storm :—

" The first sign of these storms is a low bank of dark clouds in the northwest, the upper outline of which has the appearance of an arch. It approaches at first slowly, and then more and more rapidly and arrives with a strong gust or squall. There is frequently thunder and lightning followed by downpours of rain, and sometimes hail, which is driven by the strong wind. On some occasions the wind blows with almost hurricane force. The greatest velocity of the wind recorded in one of these storms (if the record can be relied upon) was 115 miles per hour. These storms commence generally in the afternoon, rarely last more than three or four hours and are usually followed by cool and clear weather during the remainder of the night."

Throughout the southwest monsoon period the predominating winds are southwesterly on the Orissa coast and southerly to southeasterly on the Bengal coast. July and August are the rainiest months. The transformation from the local southerly winds to the winds of the southwest monsoon proper usually occurs in the second or third week of June and is generally ushered in by the advance of a cyclonic storm of moderate intensity in the rear of which the monsoon currents are carried. These storms may occasionally reach great violence. From the commencement of the southwest monsoon in June to the end of September or middle of October there is a rapid succession of cyclonic storms or depressions which form at the head of the Bay. Advancing westwards these depressions cross the coast generally between False Point and Barisal. Hence the weather in this period alternates between periods of stormy conditions with showers and rain squalls during the inception and early stages of the advance landwards of these storms, and periods of light unsteady winds after their passage inland. The southwest monsoon usually withdraws in the first half of October.

Arakan Coast (Cox's Bazar to C. Negrais).—The dry season lasts from the end of November to April. Light northerly winds with generally a slight westing prevail till the end of February. During the hot season, March to May marked land and sea breezes are experienced. In the months October-December and also April and May cyclonic storms sometimes

form in the Bay of Bengal near and to the west or northwest of the Andamans and pass by a curved path to the Arakan coast giving rise to rain and squally weather. During the rainy season, June to September, strong southerly to southeasterly winds predominate. General showers of heavy rain are frequent, and are attended at times with squalls and occasional thunderstorms. July is the rainiest month on this coast. Isolated rain squalls occur throughout August and become more frequent in September. The rainfall diminishes rapidly in October and usually ceases after a few thundershowers in the first week of November.

Lower Burma Coasts (C. Negrais to Victoria Point).—During the cold weather period, November to January the winds on the coast of Lower Burma of which Rangoon is representative, are steadily from the northeast, with a slight to moderate easting, increasing in amounts southwards. February is a transitional month during which the winds shift round to southerly directions in Lower Burma. On the Rangoon coast a feeble local southerly wind sets in early in February and gradually increases in force, marked land and sea breezes being met with. During the next three months the winds change from northwest to west and finally to southwest, with appreciable land and sea breezes near Moulmein. Showers are of occasional occurrence in March and April while general rain is of frequent occurrence in May, accompanied, near the Mergui Archipelago, with squalls, thunder and lightning. Occasionally, during April and May cyclonic storms form in the Andaman sea and travelling generally north to northeastwards affect the coast between Diamond Island and Moulmein with stormy weather. During the rainy season, June to September, the winds are generally southwesterly but steadier than in the preceding months, being from westsouthwest at Diamond Island, south to southsoutheast at Moulmein and southwest to westsouthwest at Mergui in July, which is the rainiest month on the Tenasserim coast. These winds change little in direction or strength until September when they begin to show signs of weakening and also shift towards east. They decrease steadily in strength throughout September and October. The southwest monsoon winds usually withdraw from Lower Burma coast by the end of October, and are replaced by light variable or northeasterly winds which gradually strengthen in November into the dry winds of the cold weather season.

CHAPTER IV

CURRENTS AND TIDES

Currents

The surface currents in the Indian Seas follow to a great extent the direction of the winds of the prevailing seasons. The current systems should be studied with the wind systems given in Chapter II (*Figs. 1 and 2*). The general set or direction towards which the current flows, is southwestwards during the northeast monsoon, northeastwards during the southwest monsoon and more or less variable during the transition periods. The attached charts (*Figs. 3—6*) compiled from the available current observations show the general set of the currents in the different seasons. It should however be remembered that currents are somewhat variable and the arrows in the diagram show only the mean set.

November to January (*Fig. 3*).—During this season the NE monsoon blows over the Indian Seas and exerts a large influence on the ocean currents. In the south Bay of Bengal, the current sets westward from the Malacca Straits and continues in the same direction south of Ceylon and in the South Arabian Sea. In the rest of the Bay, the current circulation is mainly counterclockwise, the set being northwestwards or westwards in the eastern and central parts of the Bay and southwestwards or southwards off the east coasts of the Indian Peninsula and Ceylon. Strong currents with speeds up to 25 miles per day are experienced off the east and south coasts of Ceylon. The circulation in the Arabian Sea is similar to that in the Bay, the set of the current being towards NW off the Indian coast and towards W and SW in the middle of the Arabian Sea and off Arabia and Somaliland.

February to April (*Fig. 4*).—From February to April, with the development of the heat low inside the Indian Peninsula, the winds off the east coast of India become southerly to southwesterly and those off the west coast become northwesterly. This is reflected in the sea currents also. In the south Bay of Bengal, the ocean current remains the same as during November to January, but off the east coast of the Peninsula, a

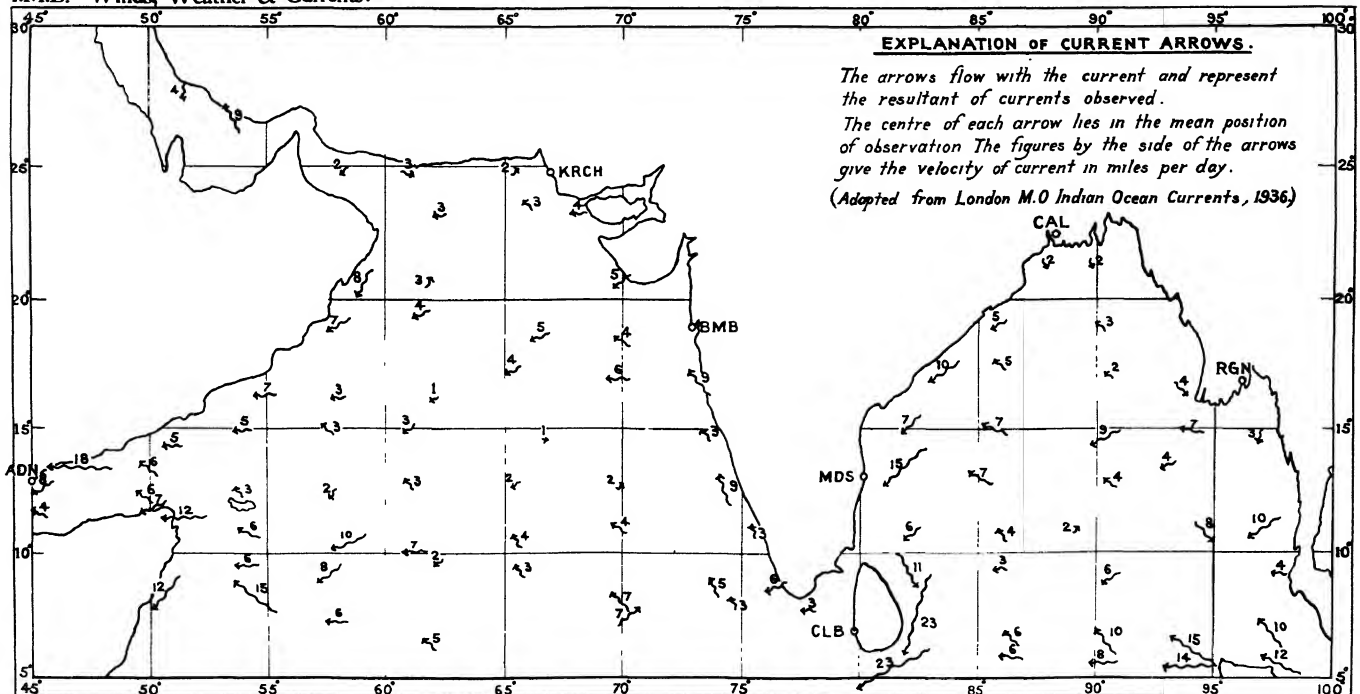


FIG. 3. CURRENTS IN INDIAN SEAS——NOVEMBER TO JANUARY.

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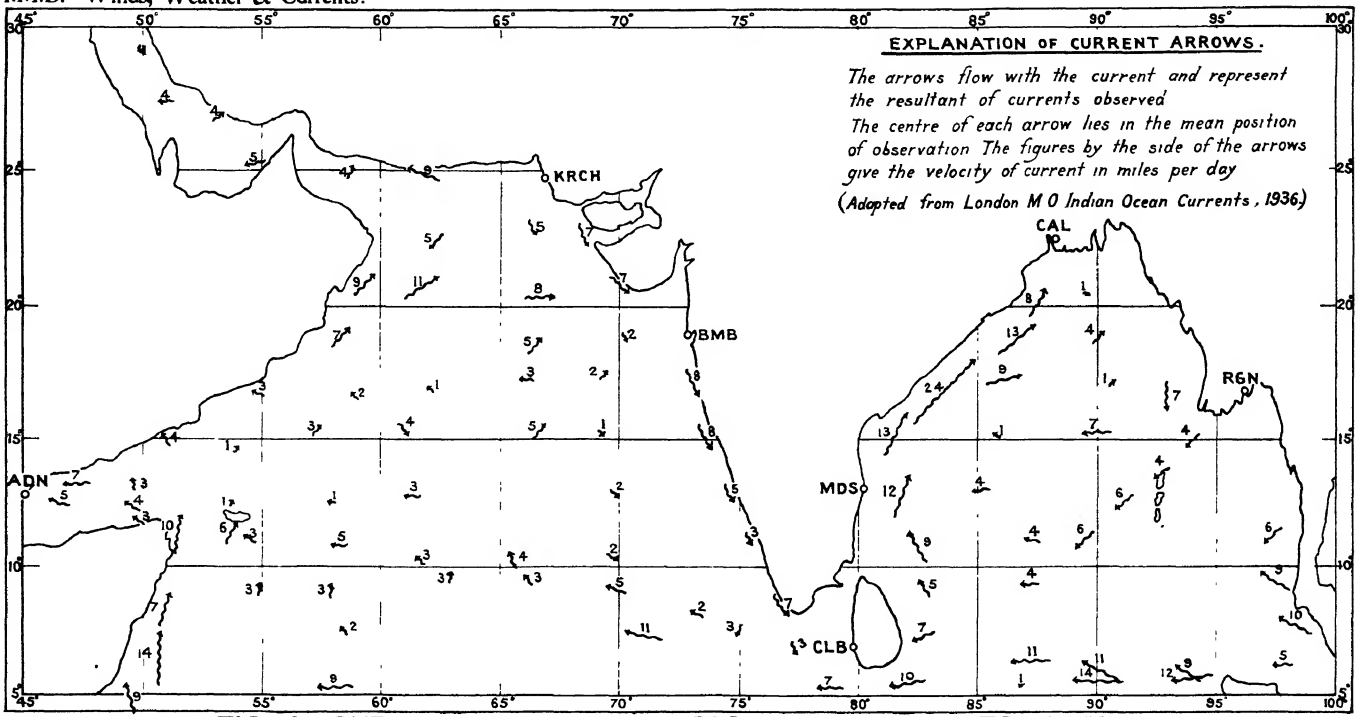

FIG. 4. CURRENTS IN INDIAN SEAS — FEBRUARY TO APRIL.

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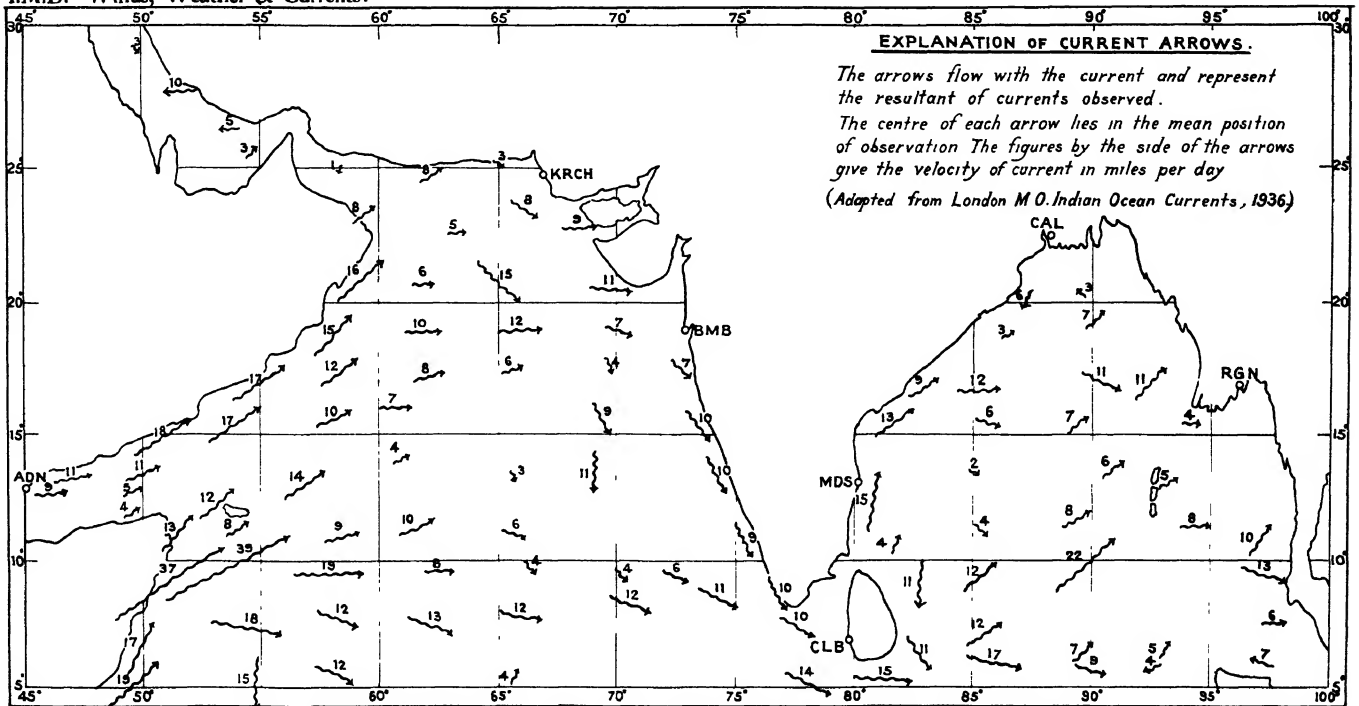

FIG. 5. CURRENTS IN INDIAN SEAS — MAY TO JULY.

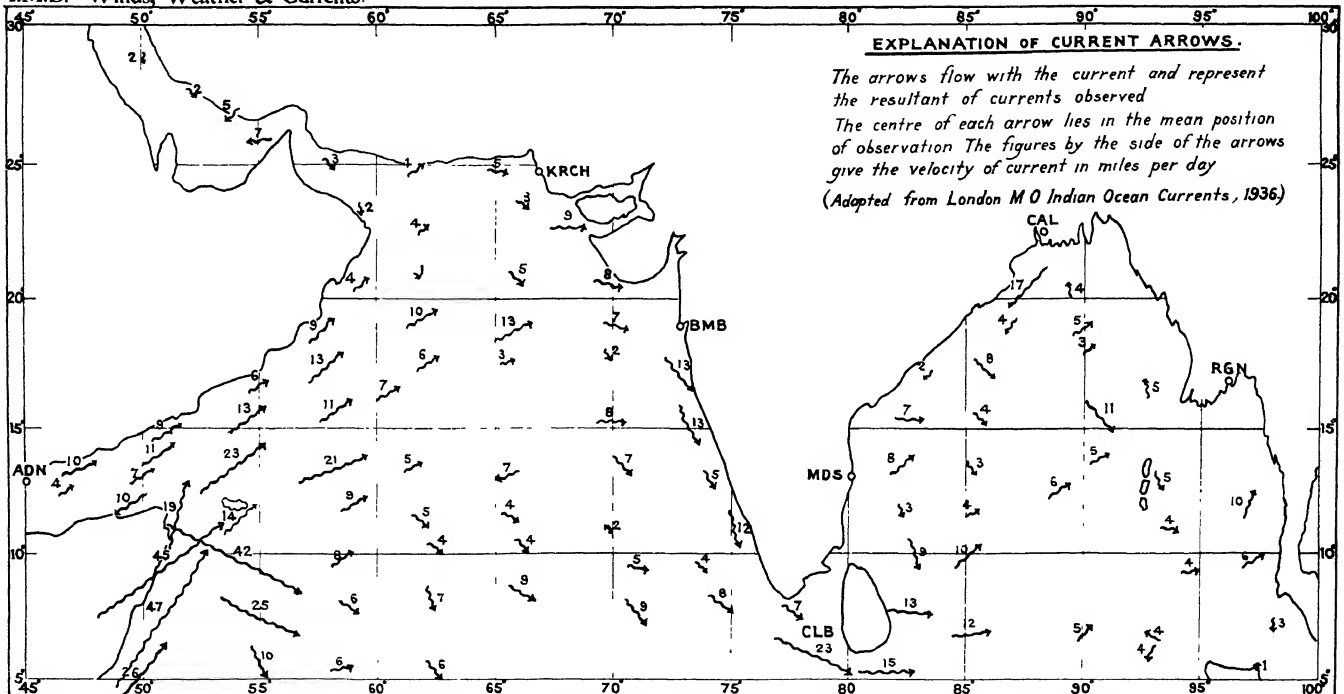

FIG. 6. CURRENTS IN INDIAN SEAS — AUGUST TO OCTOBER.

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strong current sets to N and NE and tends to complete a clockwise circulation in the northern half of the Bay. In the Arabian Sea, the set is towards SSE along the Indian coast and towards NE along the African and Arabian coasts; it is weak and variable in the central parts.

It will be seen that both in the Arabian Sea and the Bay of Bengal the current is mainly counter-clockwise in the first half of the northeast monsoon and clockwise at the end of the northeast monsoon season. This reversal of current takes place in February to March in the Arabian Sea and in December to February in the Bay of Bengal.

May to July (*Fig. 5*).—At the commencement of the southwest monsoon, the eastward coastal currents which were running parallel to the east coast of Africa and the west and east coasts of India strengthen, and practically over the whole area of the Indian seas, the current sets eastward, modified of course by the direction of the coast lines. The main regions of exceptional currents are off the east coast of Ceylon where the current set is northerly to northwesterly and at the head of the Bay where the currents are weak and tend to form an anti-clockwise circulation. The strongest currents are experienced off the Somaliland coast where drifts of 20 to 60 miles per day are occasionally found. The drifts off the Indian and Ceylon coasts are 10 to 15 miles per day.

August to October (*Fig. 6*).—In these months, the currents are similar to those in the previous three months but gradually get weaker. The change from the southwest monsoon to the northeast monsoon system takes place in October in the Bay of Bengal and in October-November in the Arabian Sea.

In *Figs. 3 to 6*, the mean drift and set of the currents in different parts of the Indian Seas in the four seasons are shown. The figures given by the side of the arrows stand for the mean drift expressed in miles per day.

Tides

The surface level of the sea undergoes a rise and fall twice in every 24 hours. The range of the tide is variable, for example, at new and full moons, the range is greater than during the quarters. Tides with high range which occur at about the time of new and full moons are known as " spring " tides and those with low range which occur about seven days from new and full moons are called " neap " tides. The range of the tides depends also on the season and the locality.

Out in the sea and on the open coasts, the tides cause only a rise and fall in the water level; but along irregular coasts this change in level starts currents which often move with great velocity. These currents aid or impede vessels on their courses and sometimes place them in dangerous positions.

Arabian Sea Coasts.—During flood tides, the tidal stream sets eastward along the coasts of Sind and Kutch, northward along the Okhamandal coast and southeastward along the Kathiawar coast up to Diu head; here the tidal current runs 1 to 1½ miles an hour to the eastward. Off Diu head the westward stream during the ebb in the Gulf of Cambay frequently causes eddies. During spring tides, bores are caused in the Gulf of Cambay and in the Mahi and Sabarmati rivers.

On the Konkan and Canara coasts where there are no indentations the tidal wave strikes the coast from the west at right angles to the mean direction of the coast line; there is thus very little difference in the times of high water on the west coast. Along the north Konkan coast the stream during the flood sets northward, increasing in strength as we go north as far as the Gulf of Cambay. From about Jaigarh (one hundred miles south of Bombay) to Mangalore and Mount Dilli no tidal stream is observed along the coast, except just off the mouths of the rivers; at these places the stream at the flood sets on the mouth of the rivers and that at the ebb seems to run out to sea. Southward of Mount Dilli the stream during the flood is just felt as coming from the northwest which becomes plainly marked at Cochin. At Cochin and Tuticorin a feature of the

tides is their susceptibility to the influence of the wind ; sudden changes of the level of the water, as much as one foot in an hour, due to wind, have been recorded.

Ceylon.—At Colombo four floods and four ebbs have been observed in the course of 25 hours, but the tidal range or difference between the high and low water levels is only six inches. The Maldive Islands divide the tidal flow and give rise to two northward currents : the one which inclines eastward flows towards the Gulf of Manar and causes high water at Colombo and Cape Comorin at about the same time.

The Bay of Bengal Coasts.—The tidal wave appears to move in a northerly direction into the Bay of Bengal. The spring tides are highest in the day during summer and in the night during winter.

Near the coast at the head of the Bay flood tide sets towards the north and in the Gulf of Martaban to a northeasterly direction.

Between the Nicobar Islands and the Malacca Straits there are occasionally lines of heavy breakers which occur in deep water. In the Straits of Malacca the flood tide sets to the east ; the ebb stream is, however, the stronger.

On entering some river mouths the tidal current takes the form of a single tidal wave of great volume, known as the " bore ", which travels rapidly up-stream.

Bores mainly occur at the spring tides during the southwest monsoon. The best known of these bores are those at the entrance of the Hoogly and the Meghna rivers of Bengal, and of the Sittang and the Pegu rivers of Burma. Generally speaking, the height of a bore in the navigable channels is not such as to affect a ship ; but small craft should move out of its way or move off from the shallow into the deep part of the river.

CHAPTER V

TROPICAL REVOLVING STORMS.—THE LAWS OF STORMS AND RULES FOR HANDLING SHIPS

General

A tropical storm or cyclone is a vast whirl in the atmosphere in which the wind blows round and towards a central region of low barometric pressure. The winds associated with a tropical cyclone are the most violent on earth, the rainfall is torrential and the heaviest sea and swell are experienced near its centre. In the northern hemisphere* the air in the field of a cyclone circulates in a direction opposite to the hands of a watch around the centre of low pressure. In a fully developed cyclone there is usually a core of light winds or even a calm at the centre and this is surrounded by a belt of hurricane winds.

These storms have a progressive movement, the storm-field advancing on a curved or, sometimes, a straight track. They generally originate in tropical seas from 5° to 20° of the Equator. Their velocity of movement averages about two to three hundred miles per day. Generally during curving, their rate of advance decreases considerably.

In front of a tropical cyclone, the sky is covered with high clouds in which halos sometimes appear. The air becomes sultry and oppressive ; the wind falls almost to a calm, and on the ocean a heavy swell rolls up. In the next stage a breeze springs up, the clouds become lower and heavier, and pressure begins to fall. Afterwards heavy rain-clouds appear, first on the horizon, and then advance across the sky ; as the rain-clouds pass overhead, the rain falls in torrents. The wind becomes fiercer reaching a strength of 10 to 12 on the Beaufort scale, while the barometer falls rapidly. High or tremendous seas are superimposed on the heavy swell. The sea spray and rain destroy all visibility. When the wind has reached its greatest violence, suddenly the centre of the storm arrives. Here the wind drops from hurricane force to a light unsteady breeze, or sometimes to a complete calm. At the calm centre the lowest pressure is recorded and often there is a complete absence of low cloud and rain ; the sun, moon or stars may be

* In the same direction as the hands of a watch in the *southern hemisphere.*

visible according to the time of day when the calm centre is traversed. Following the passage of the centre, the wind suddenly increases to hurricane force again but from the opposite direction; the torrential rain is renewed and the barometer rises as quickly as it fell. As the end of the storm approaches, the wind falls and the rain-clouds break and disappear, leaving only high clouds. Finally the wind drops, the sky clears and pressure becomes normal.

Nomenclature.

The calm centre is sometimes called by seamen the "*Eye*" or "*Vortex*" of the storm. A striking feature of the eye is that grass-hoppers and butterflies, and sometimes land birds which have been sucked into the whirl are dropped dead or in a state of complete exhaustion. The eye of the storm is often almost as dangerous for navigators as the surrounding ring of strongest winds, because at the centre the sea is excessively turbulent and high owing to the "churning" action produced by heavy swell arriving from all sides of it. The diameter of the calm central region of a cyclone may vary from 4 to 30 miles and the thickness of the belt of hurricane winds from 4 miles to 30 or 40 miles.

Track: the track along which the centre of the storm has travelled.

Path: the path along which the centre of the storm will probably travel.

Right Semicircle: that half of the storm which lies to the right when looking along the path in the direction of movement of the storm.

Left Semicircle: that half of the storm which lies to the left when looking along the path in the direction of movement of the storm.

Trough: a line drawn through the centre of the storm at right angles to the track. In front of the trough the barometer is falling and behind the trough it is rising. Near the trough the wind direction may change suddenly and there may be torrential rain.

*Dangerous Quadrant**: the advance quadrant of that semicircle which lies on the side of the path nearest to the usual

* In the *southern* hemisphere the *left-hand* semicircle is the dangerous semicircle and *right-hand* semicircle the *navigable semicircle.*

direction of recurvature ; it is so named because a ship caught in the dangerous quadrant may be blown towards the path over which the ring of hurricane winds and the centre will pass, or the storm may recurve and pass over her. It should be noted that the strongest winds are usually found in the rear of the trough, hence it often blows hardest with the first rise of the barometer.

*Navigable Semicircle** : that semicircle which lies on the side of the path farthest from the normal direction of recurvature.

Centre : at the centre of the storm the barometer is always lowest and there is comparative calm ; here the sea is extremely dangerous, being the meeting place of heavy swells from all directions.

When the centre approaches a ship, she experiences increasing wind with violent squalls, later perhaps hurricane force with mountainous seas ; as the centre passes over her the wind drops ; when it has passed, the wind comes from the opposite point of the compass with renewed and increased violence ; as the storm moves away from the position of the ship the wind moderates ; this is illustrated by A, A_1, A_2, etc., shown in *Fig. 7*. Much rain, thunder and lightning may be experienced.

Vertex : the most westerly point reached by the centre when recurvature takes place. Also known as the *Cod* of the Track.

Angle of Indraft : the angle which the direction of the wind makes with an isobar or line of equal pressures.

The terms explained above are illustrated in the figure.

Precursory Signs.

The indications of the approach of or entrance into tropical revolving storms are :—

(1) *Swell* : In the right hand rear quadrant of a storm (in the left hand rear quadrant in the southern hemisphere) the action of the violent winds blowing mainly in the direction of advance of the storm develop large waves which pass onward as swell. This swell travels to great distances and at a

* In the *southern* hemisphere the *left-hand* semicircle is the dangerous semicircle and *right-hand* semicircle the *navigable semicircle*.

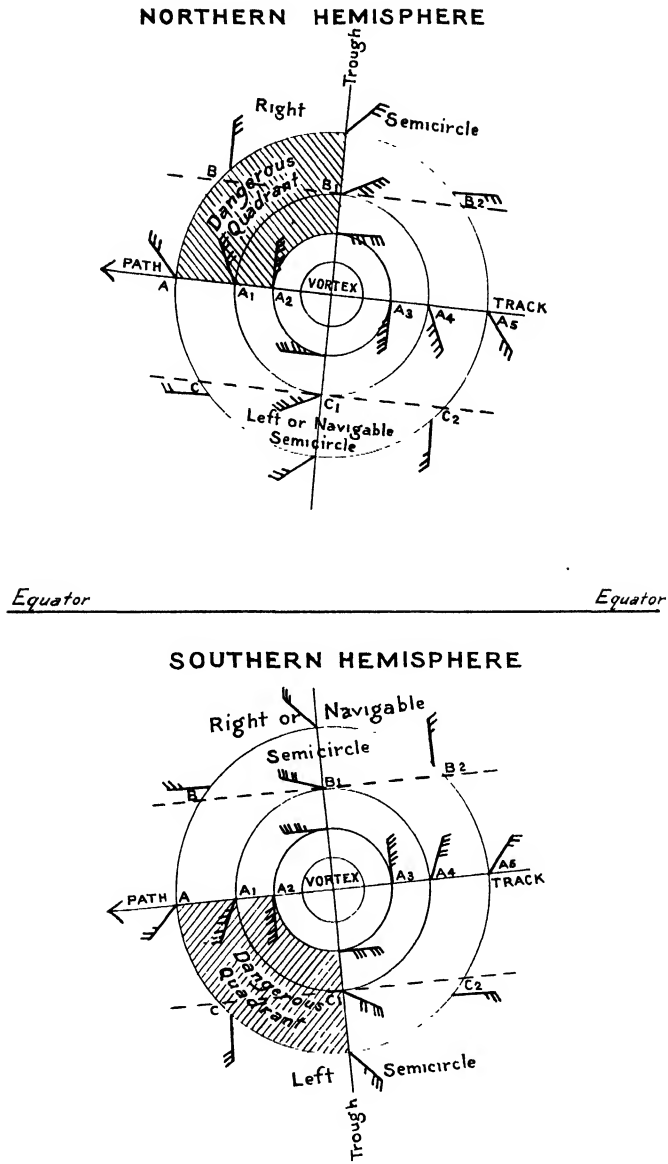

Fig. 7. Diagrammatic Representation of a Tropical Storm.

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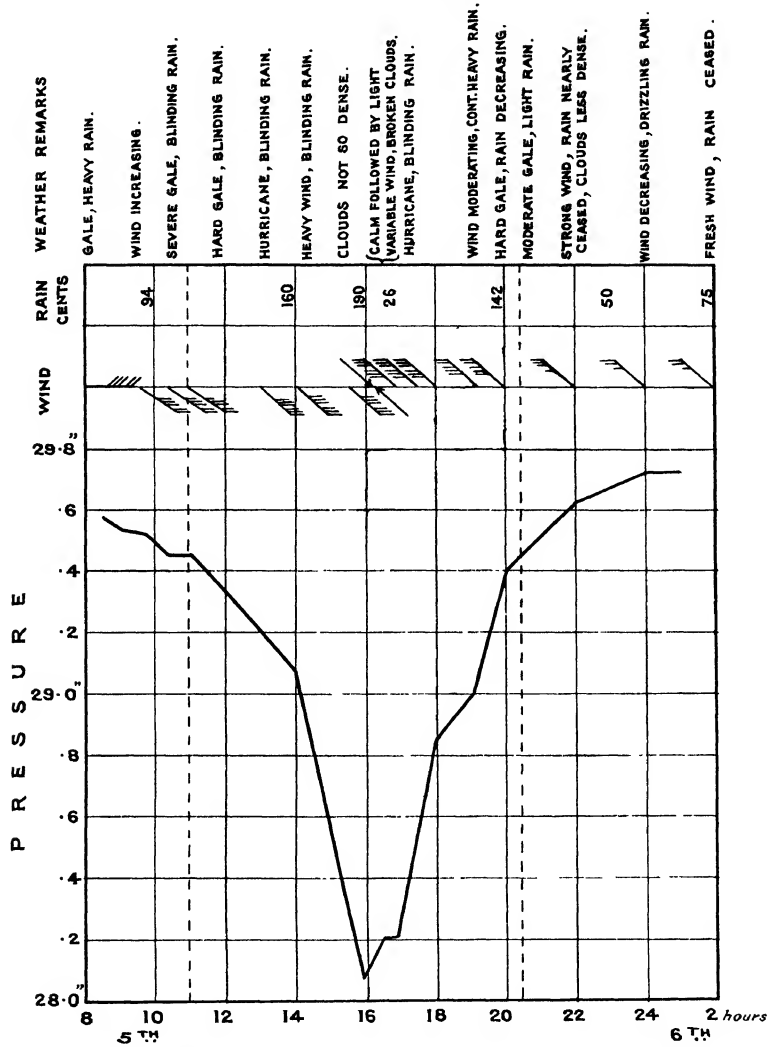

Fig. 8. Changes of pressure, wind and weather experienced during the passage of a cyclone. (Observations recorded at False Point in Nov. 1891)

greater speed than the storm so that a long heavy swell coming approximately from the direction of the storm frequently forewarns an observer of the existence of a storm, occasionally by as much as two days before the other local indications of wind and cloud are sufficiently definite. The swell may extend to a distance of 1000 miles from the storm centre.

(2) *Barometer*: There is a fall in the barometer, more or less below its normal height. If the atmospheric pressure is 1/10 of an inch below the normal value for the time of the day, the mariner may apprehend that a storm has formed or is forming in the vicinity and should be on the alert for other signs. The old idea that there is no diurnal change of pressure in the field of a cyclone is exploded; the diurnal change continues but becomes less noticeable near the centre on account of the magnitude of the change due to the storm.

The following table gives the mean corrections which have to be applied to the readings of the barometer in Indian Seas between Lat. 10°N. and 20°N. in order to correct them to the mean value for the day.

TABLE II.

Local Time.	Corrections to be added in millibars.	Corrections to be added in inches.
4 a.m.	+0·8	+·02
8 a.m.	—1·0	—·03
Noon	—0·8	—·02
4 p.m.	+1·3	+·04
8 p.m.	0·0	·00
Midnight	—0·3	—·01

The barometer falls continuously in passing from the outskirts to the storm area; the fall is slight in the outskirts, but it is more and more rapid as the inner storm area is approached. At the centre of an intense cyclone the barometer may stand fully 2 inches lower than outside the storm field. Usually, however, the fall of pressure in the centre of a storm in Indian Seas is only 0·3″ to 1·0″. The variations of pressure, wind

and weather experienced at a station during the passage of the very severe False Point cyclone of 1891 are shown in *Fig. 8.*

(3) *Weather*:

(*i*) Sometimes a peculiar dark red or copper colour of the sky at sunset forebodes a storm.

(*ii*) A threatening appearance of the weather. The appearance of a peculiarly dense heavy bank of clouds on the horizon, its position being shown at night by the almost continuous lightning from distant clouds.

(*iii*) The occurrence of a succession of squalls (sometimes rain-squalls) which increase in frequency and intensity while the wind rises. The squalls usually come from the right of the wind direction, but sometimes accompany shift of wind.

Laws of Storms.

When sailing in the region and in the season of revolving storms, the mariner should be on the watch for the precursory signs and carefully observe and record the wind and the barometer. When the wind, the barometer, the appearances of the sky and sea indicate the approach of a cyclonic storm, it is important to ascertain—

(*i*) *the probable bearing of the storm centre, and when in the storm field,*

(*ii*) *in which part of the storm area the ship is situated.*

In order to ascertain these two points it is necessary that the observer should be stationary. Therefore, the first thing to do is to stop head to wind or heave to. There should be no hesitation in doing so because the sooner a clear knowledge of the position of a ship in the stormfield is ascertained, the sooner will it be possible to take any action that may be necessary to avert danger. In heaving to, it should be assumed that the ship is in the dangerous quadrant and hence, in the northern hemisphere, heave to on the starboard tack (on the port tack in the southern hemisphere).

(1) *Buys Ballot's Law.*—In the northern hemisphere if you face the wind, the barometer will be lower (higher in the southern hemisphere) on your right hand than on your left.

This law, known as Buys Ballot's Law, should be clearly borne in mind, as by its application the probable bearing of the storm centre can approximately be ascertained. Thus having hove to on the starboard tack, face the wind and the bearing of the storm centre will be from 12 to 8 points of the compass to the right hand (left hand in the southern hemisphere). Allow 12 points at the beginning of a storm, 10 points when the barometer has fallen 3/10 of an inch (10 millibars) and 8 points when the barometer has fallen 6/10 of an inch (20 millibars) or more.

The direction of the ocean swell affords another indication of the bearing of the centre, for the swell comes approximately from the direction of the storm centre.

(2) Having ascertained the bearing of the centre, the semicircle in which the vessel is situated may be found by observing in which direction the wind shifts when hove to.

Thus (*i*) if the wind veers*, *i.e.*, the ship is in the right-hand semicircle (see positions B, B_1, B_2, etc., in *Fig.* 7), (*ii*) if the wind backs† or shifts to the left, the ship is in the left-hand semicircle (see positions C, C_1, and C_2 in the figure), and (*iii*) if the wind remains steady in direction and increases in force with falling barometer the vessel is near or in the direct path of the storm centre.

This law holds good for both the northern and southern hemispheres.

Rules for Handling Ships.

A.—In the northern‡ hemisphere:

(*i*) If your ship is in the right semicircle and she is a sailing vessel, remain hove to on the starboard tack,

---

* Veering.—West to North to East to South.

† Backing.—West to South to East to North.

‡ The rules for the southern hemisphere are:—

(*i*) If the ship is in the right semicircle, whether she be a sailing vessel or a steamship, run with the wind on her port quarter until the barometer commences to rise.

(*ii*) If in the left semicircle, and if she be sailing vessel, remain hove to on the port tack; if a steamship, heave to with the wind ahead if possible and if not, with the wind on the port bow.

(*iii*) If in the path of the storm, run the ship, whether a sailing vessel or a steamship, with the wind on the port quarter; this will take the ship to the right or navigable semicircle.

so as to come up to wind and sea as the former continues to draw aft; if a steamship, heave to with the wind ahead at right angles to the assumed path of the storm if possible, and if not, heave to with the wind on the starboard bow.

(*ii*) If your ship is in the left semicircle, whether she be a sailing vessel or a steamship, run with the wind on the starboard quarter away from and at right angles to the assumed path of the storm until the barometer commences to rise.

(*iii*) If the wind remains steady in direction and increasing in force with falling barometer, the ship is near or in the direct path of the storm centre and the seaman should run his ship, whether a sailing vessel or a steamship, with the wind on the starboard quarter until the barometer begins to rise; this will take the ship into the left or navigable semicircle.

B.—Should a vessel not have sufficient sea-room to run when in the navigable semicircle, she should heave to on the port tack.

C.—If in a harbour or at anchor, the seaman should be just as careful in ascertaining the bearing of the centre and watching the shift of the wind as by so doing, he will be able to tell on which side of the path of the storm he is situated and be able to act according to circumstances.

With wireless telegraph equipment it is possible for the navigator to obtain information about the position, intensity and movement of storms by collecting weather reports from other ships in the sea or from land, and combined with such information, the rules given above will enable him to avert danger to a great extent. It is better to proceed at full speed ahead of the storm into some recognised shelter rather than be caught in narrow waters, as the visibility may become very low owing to driving rain and spray and frequently quite large sets are experienced.

Effect on current of a tropical storm.—In the neighbourhood of a tropical revolving storm, the set of the current may be very different from the normal set. The storm gives rise to a set radially outwards from its centre and the current actually experienced in its vicinity will be the resultant of the normal current and the current due to the storm. When the normal current is weak, the radial outflow will be predominant and unless the mariner makes due allowance for this set, serious errors in reckoning may be made. In one case, a vessel experienced a southeasterly set of more than 50 miles in a situation when the normal set was southwesterly.

Conclusion.

Once a ship enters the wind circulation of a storm, her commander will be best guided by—

(*a*) his own observations,

(*b*) reports from other ships in the vicinity, and

(*c*) weather bulletins and warnings issued through the coastal wireless stations from the Weather Offices at Poona and Alipore, Calcutta.

CHAPTER VI.

CYCLONIC STORMS IN THE INDIAN SEAS.

In the Indian Seas, cyclonic storms of dangerous severity occur most frequently in the seasons of change of monsoon—April to June and October to December. These storms commence as feeble circulations and grow gradually; they are of varying intensity and magnitude. A storm may be of great extent and feeble intensity or of small extent but violent intensity.

In practice, the India Meteorological Department uses the term "depression" for those cyclonic circulations in which the wind does not reach gale force, *i.e.*, does not exceed force 7 on the Beaufort scale; when there is evidence or reason to believe that the wind in any part of the cyclonic area has risen to gale force (force 8) the distrubance is called a "storm" with wind force 10 or more and occasional hurricane squalls, the storm is said to be severe.

There are many recorded instances of storms having passed from the Gulf of Siam across the Malay Peninsula into the Bay of Bengal; but by far the greater number of storms experienced in the Bay forms in the Bay itself.

The storms that frequent the Arabian Sea may be divided into two groups, *viz.*, those that form in this sea itself and those that enter it across the Indian Peninsula from the Bay of Bengal. No storms formed in the Arabian Sea are known to have passed into the Bay across the Peninsula.

During the pre-monsoon period, storms occur less frequently in the Bay of Bengal than during the southwest monsoon period, *i.e.*, June to September, when there is a rapid succession of storms. These are formed at the head of the Bay; they cause strong westerly and southwesterly winds over the centre and north of the Bay and the winds remain strong even after the storm centre has passed inland. These storms are generally of moderate extent and intensity, and rarely have the inner belt of hurricane winds or calm centre. In the majority of cases strong winds are only experienced in their south and southeast quadrants.

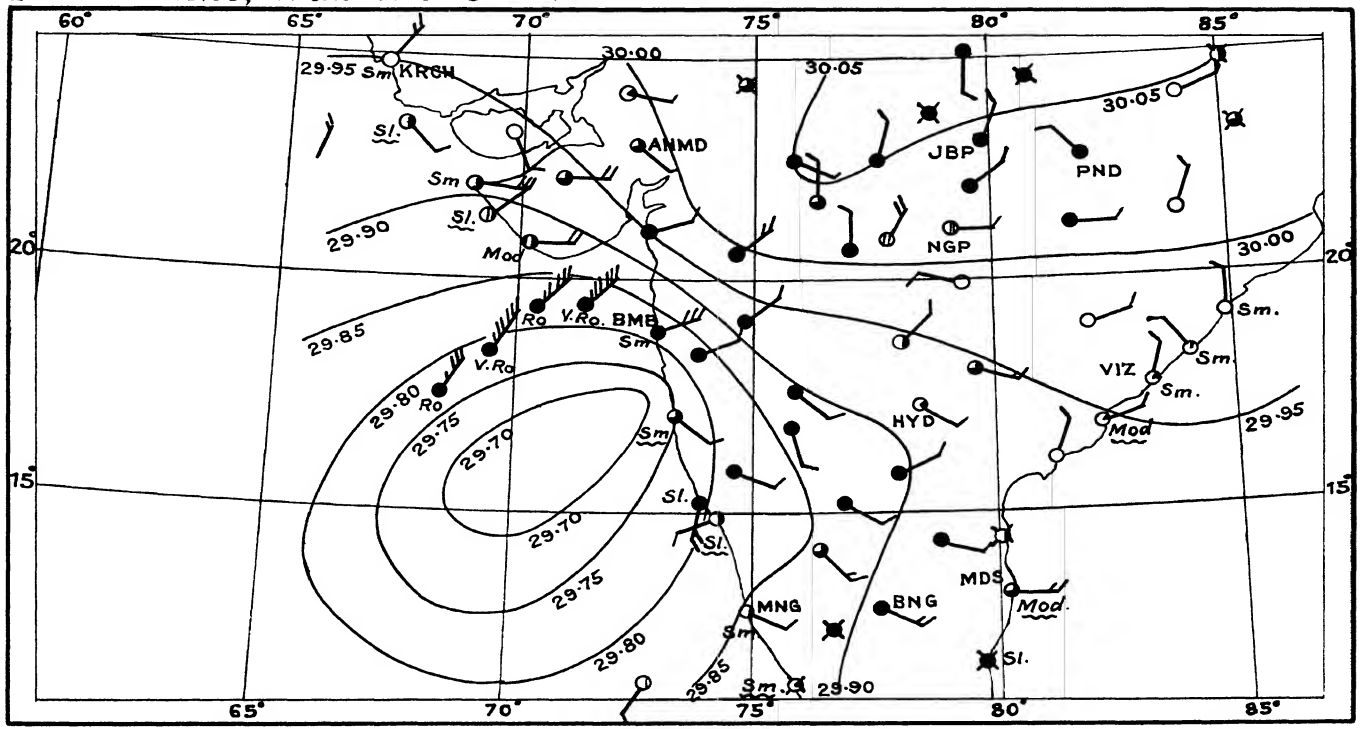

FIG.9. WEATHER CHART OF 12 TH NOV. 1927.

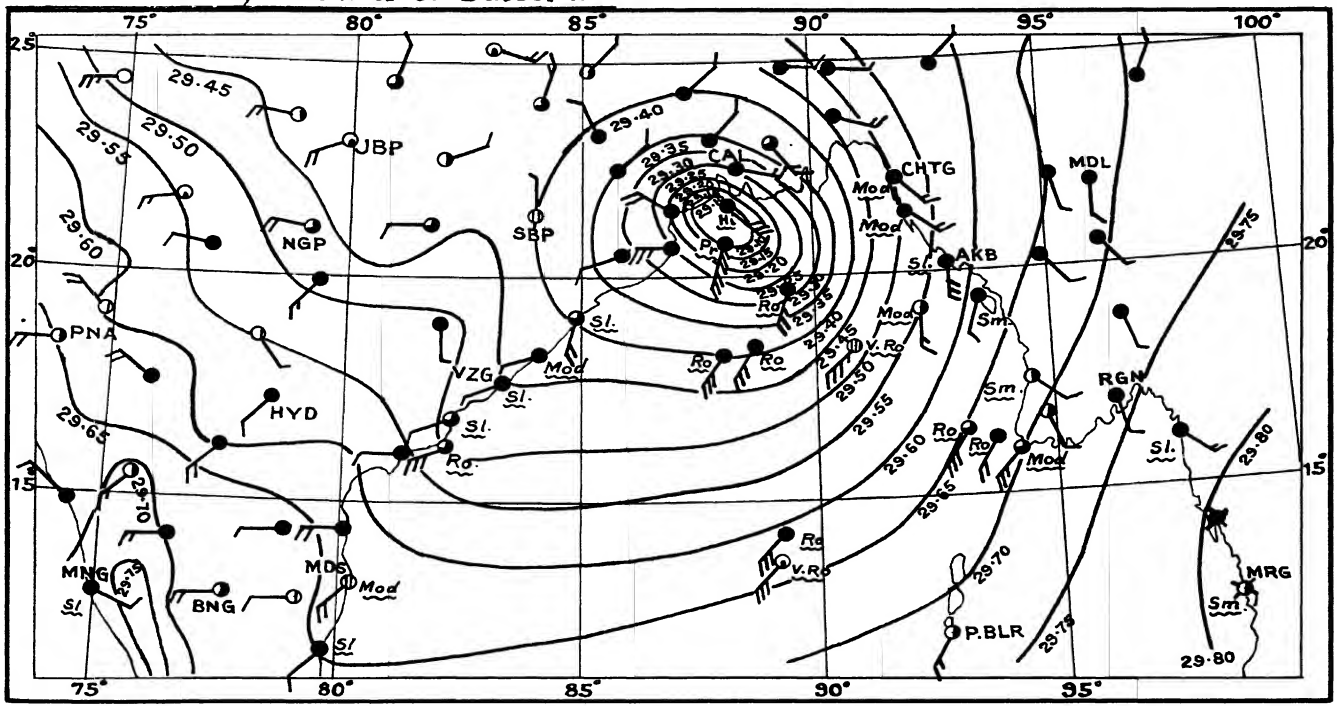

FIG.10. WEATHER CHART OF 27 TH MAY 1936.

6 P2 P PUNA/1942

To face page 35

Cyclones of the post-monsoon period, *i.e.*, October to December are generally of great intensity, and may have a well-marked inner area of stormy winds and a calm centre. The drift of surface water in the inner storm area of severe storms may be as much as 6 to 8 knots; and near the head of the Bay of Bengal the current may be found to be even stronger than this. For example, the S. S. "*Zayani*" bound from Aden to Bombay was caught up in a cyclone in the Arabian Sea from noon on November 5th, 1919, until the afternoon of November 7th, and was carried during that time about 200 miles north-west of her dead reckoning. She was in the calm centre for about half an hour from 3 a. m. on November 6th. During another cyclone in the north Bay of Bengal from 4th—6th May 1923, the Captain of the S. S. "*Angora*" who was running up the Bay behind the storm found that he had been twentyfive miles eastsoutheast of his reckoning.

Amongst the October and November cyclones of past years are to be found many examples of the most intense tropical storms. They are usually of small extent, occasionally not exceeding two hundred miles in diameter. Hence, the shifts of wind accompanying them are usually very rapid and dangerous to vessels. The winds are exceptionally violent and of hurricane intensity in the inner storm area. The rain is usually described by sailors as falling in torrents. Another important feature of these cyclones is the piling up of a mass of water in the inner storm area. This advances with the storm and strikes the coast as a "storm-wave". The effect of this in flooding the coastal districts depends largely upon the phase of the ordinary tidal wave at the time when the storm-wave strikes the coast. If the storm wave strikes the coast at about or shortly after the time of high water, it may produce the most disastrous results, flooding low coastal districts in a few minutes to depths of 10, 20 or even 30 feet above high tide level. Such inundations have occurred at intervals during the past century on the Madras coast, up the rivers Hoogly and Meghna on the Bengal coast and on the Arakan coast with disastrous suddenness, overwhelming a large part of the population in the inundated districts.

In *Figs. 9* and *10* are reproduced two weather charts showing the distribution of pressure, winds and sea associated with two

storms, one in the Arabian Sea in November 1927 and another in the Bay of Bengal in May 1936.

Storm of 10th—13th November 1927.—A depression formed in the Arabian Sea on the 10th November with centre near Lat. 12° N and Long. 68°E. It slowly gathered strength and moved first northward, then northeastward. It became a storm on the early morning of the 12th and developed into a severe one by 8 hrs. on the 12th with centre about 200 miles SW of Bombay near Lat. 17°N and Long. 70°E. Northeasterly winds of storm force and rough seas prevailed off the Konkan-Kathiawar coasts in the northern semicircle. The storm crossed coast to the south of Bombay near Jenjira in the early morning of the 13th and rapidly weakened thereafter.

The storm played havoc on coastal craft and fishing boats. It must have had a narrow core of hurricane winds and was one of the most disastrous storms that have struck the Konkan coast in recent times. Two coastal steamers s.s. " Sant Tukaram " and s.s. " Jayanti " which left Bombay for southern ports on the morning of the 12th foundered near Jenjira with a total loss of life of more than 200.

Severe storm of 22nd—29th May 1936 in the Bay of Bengal.—This storm formed in the Bay of Bengal in association with the advance of the southwest monsoon. A depression was first located near Lat. 12½°N and Long. 83°E, on the afternoon of the 22nd. It moved in a NE'ly direction and became a storm on the morning of the 26th. When it passed near Sandheads on the early morning of the 27th it was a storm of severe intensity. The storm passed over Saugor Island between 1000 hrs. and 1200 hrs. on the 27th. The following extracts from the report of the Commander of the River Survey Vessel " Guide " which was anchored in the Karapara creek at a distance of 17 miles to the north by east of Saugor Island Lighthouse bring out vividly the kind of weather that is experienced when a cyclone passes over a station.

" On the 26th, the sky was completely overcast with low-lying heavy oily clouds, which moved rapidly in a westerly

direction. Throughout the day the wind blew from an easterly direction, varying between ENE and E/S, accompanied by frequent rainsqualls.

The 27th dawned with similar signs, but more pronounced. The wind was still from the eastward, but increasing in force, and the squalls heavier and more frequent. At noon, however, the wind was noticed to abate, and at about 1300 hrs. it was practically calm, although the wind was noticed to veer from ENE through E and S to SW. At about 1430 hrs., it suddenly strengthened and blew from the westward, rapidly increasing to force 12 by about 1445 hrs. The rainfall during the calm period was slight, but a heavier driving rain was experienced with the increase of the wind. This strong blow from the westward continued for nearly four hours, accompanied by spells of heavy rainfall. Finally at about 2000 hrs. the wind abated and moved round to WSW.

The lowest pressure recorded was 28·91″ at 1400 hrs. on the 27th, and the strongest blow was experienced at 1445 hrs. when the force was quite 70 miles per hour."

The above observations show that at the time of crossing the coast, the storm had a central calm region of about 20 miles diameter.

The number of occasions on which cyclonic storms have occurred in each month in the Indian Seas are given in *Table III*. The places of origin and typical tracks of some storms are illustrated in the accompanying charts of Storm Tracks, *Figs. 11—20*. Severe storms are indicated by thick lines and other storms by thin lines.

TABLE III.—*Number of cyclonic storms reported in Indian Seas during 1891—1937.*

Region. \ Period.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
Arabian Sea	3	0	0	3	11	15	4	0	4	14	15	3	72
Bay of Bengal	3	0	4	15	19	25	22	14	19	33	39	19	212

JANUARY, FEBRUARY AND MARCH.

ARABIAN SEA.—The Arabian Sea is practically free from cyclonic storms during these months, but local gales and squalls due to storms travelling eastward through Persia and Baluchistan may be experienced along the Mekran and Sind coasts. Even these become less severe in February and are of rare occurrence in March.

BAY OF BENGAL.—The Bay of Bengal is also practically free from cyclonic storms during these months ; the few storms that have been recorded formed off Ceylon west of Long. 86°E. They may be of from moderate to severe intensity and may move in any direction between SSW and NNW.

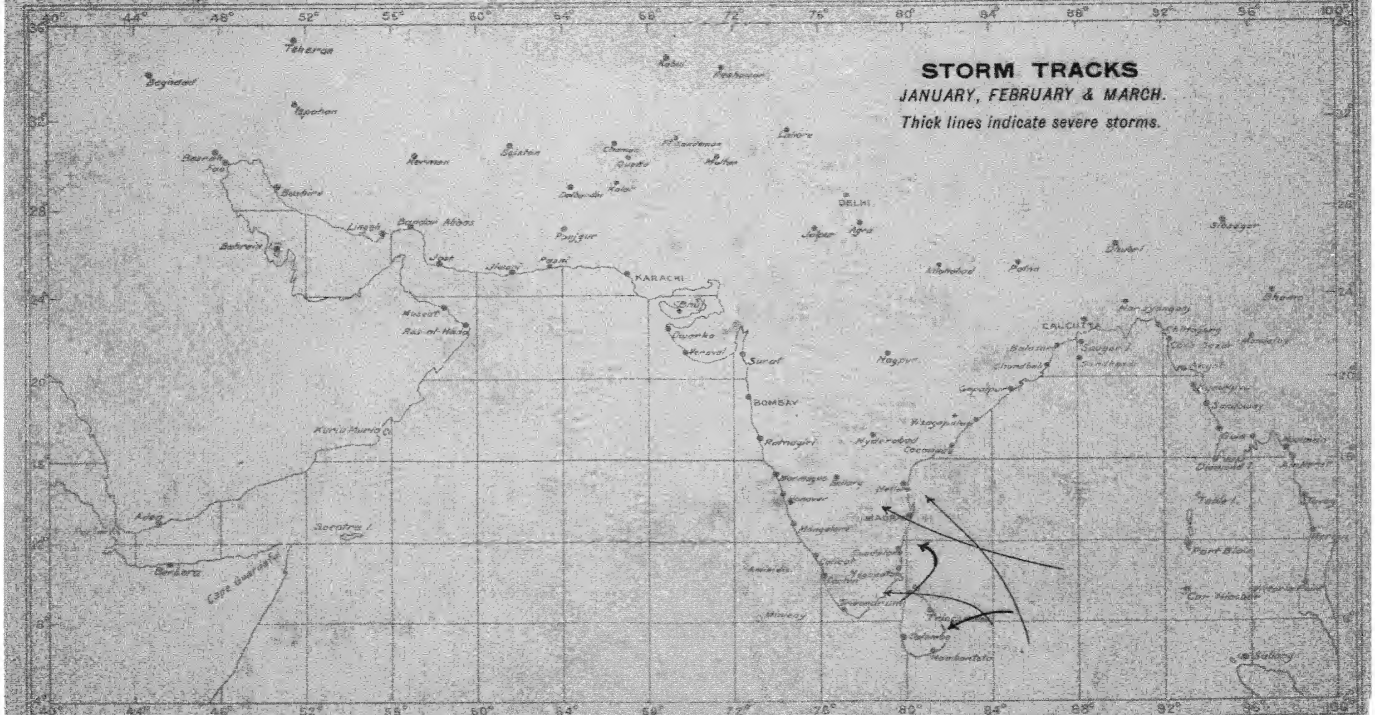

FIG. 11.

To face page 38.

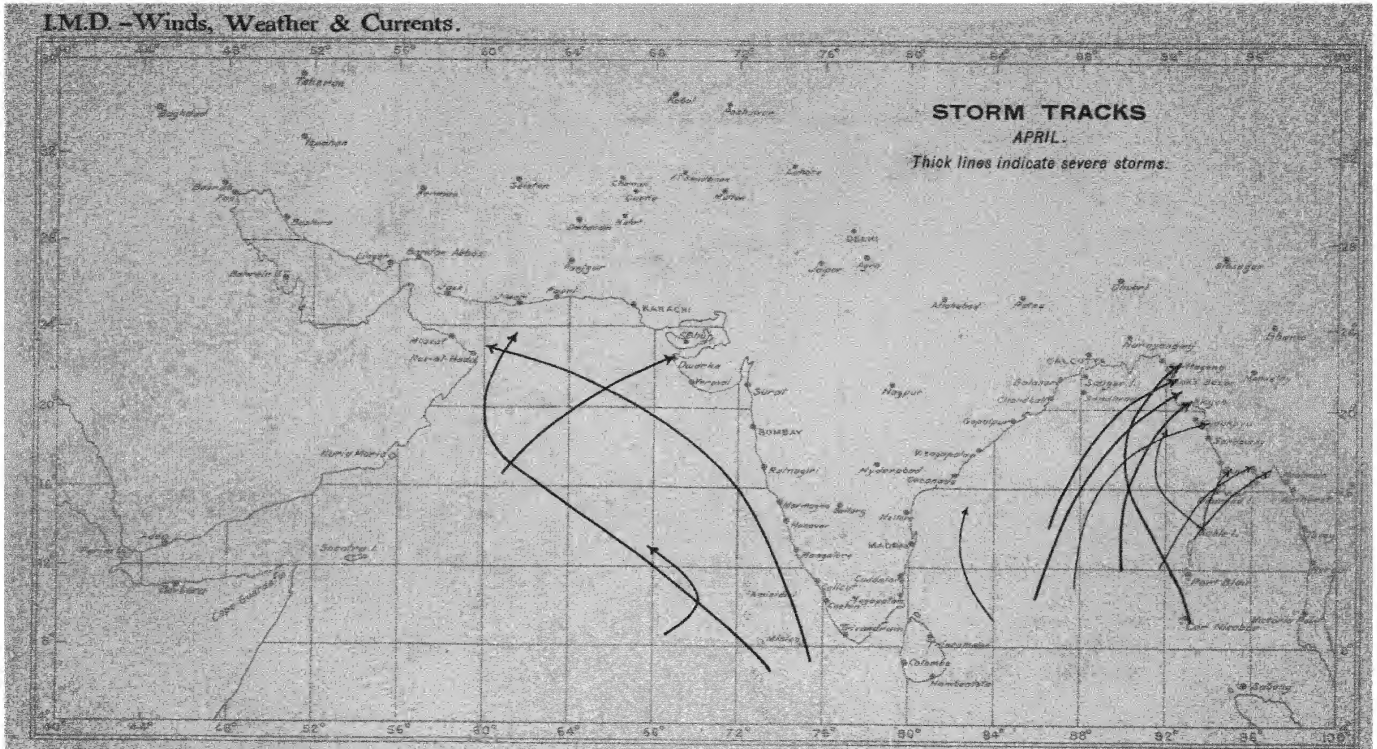
STORM TRACKS
APRIL.
Thick lines indicate severe storms.
KARACHI
BOMBAY
DELHI
CALCUTTA
Port Blair
Car Nicobar

FIG. 12.

APRIL.

ARABIAN SEA.—Storms may occur, though not frequently during the latter half of the month. They are often severe and any part of the Arabian Sea except the southwest may be visited by them. Their usual course is northnorthwestward at some distance from the west coast of the Peninsula, and then across the head of the Arabian Sea recurving to the NW or NE.

BAY OF BENGAL.—The storms of this month, some of which are severe, form in the south Bay of Bengal and less frequently in the Andaman Sea. They generally move in a N or NE direction towards the Burma and Pegu coasts.

MAY.

ARABIAN SEA.—There is noteworthy increase in the number of storms recorded in this month, most of them being severe. They form in any part of the Sea south of Lat. 14°N, and travel in a direction generally between west and northnorthwest. Some of the storms which begin by travelling NNE recurve northwestwards.

BAY OF BENGAL.—Storms, which are mostly severe, are of comparatively frequent occurrence during May. They generally form in the centre of the Bay or in the Andaman Sea, and travel in a NNW direction, frequently curving to the NE.

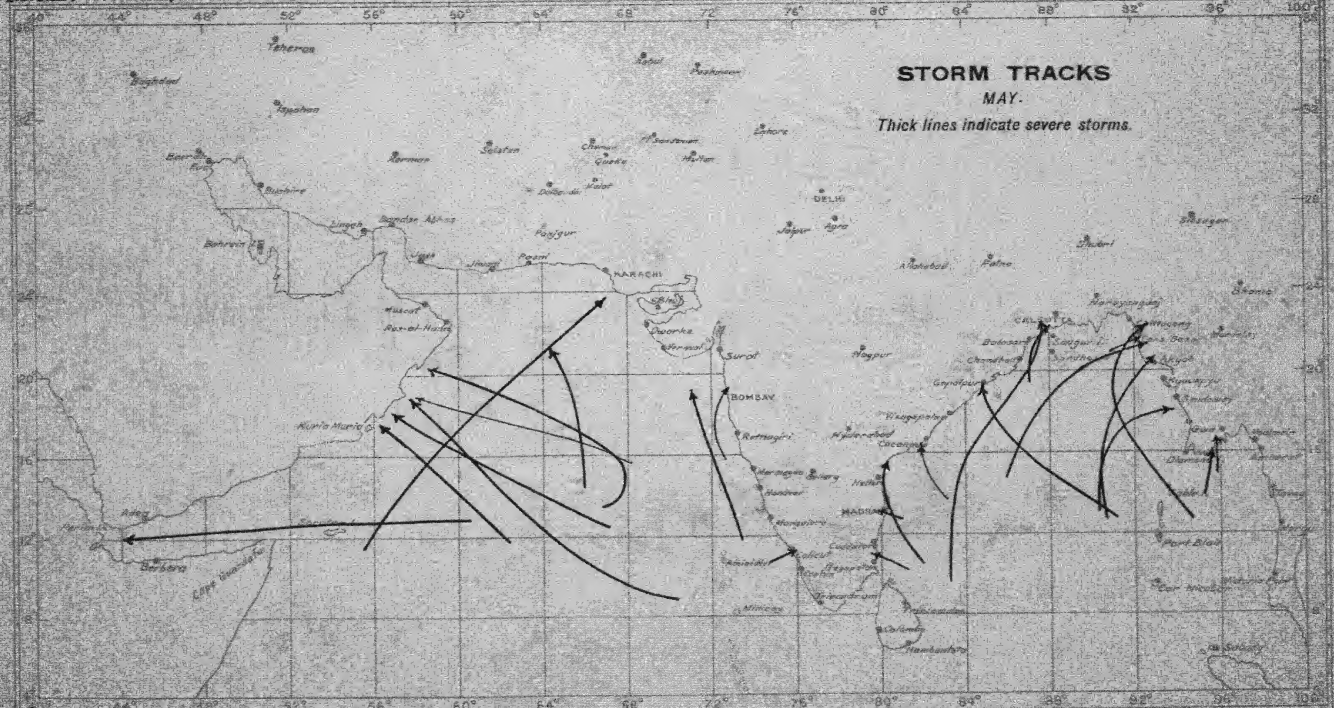

FIG. 13.

To face page 40.

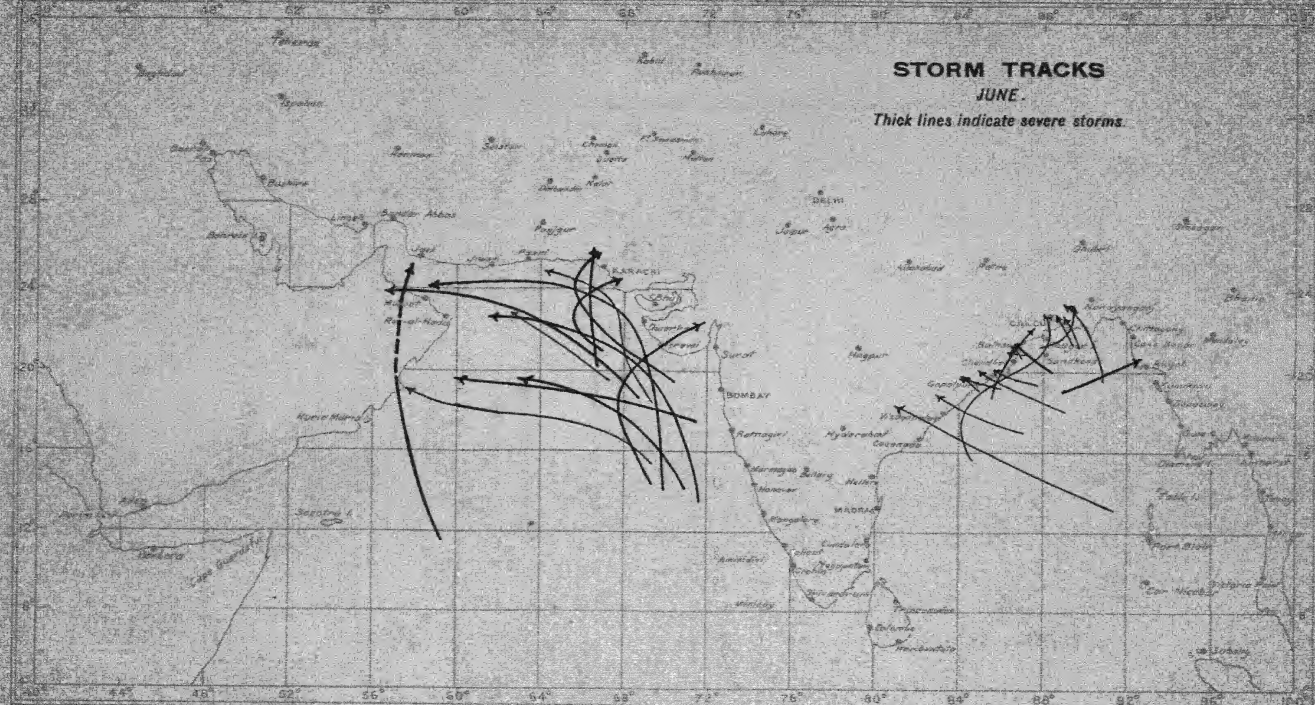
STORM TRACKS
JUNE.
Thick lines indicate severe storms.
KARACHI
BOMBAY
MADRAS
DELHI

FIG. 14.

JUNE.

ARABIAN SEA.—Storms are frequent in this month and are mostly of a severe nature. Practically all form during the first fortnight of the month and eastward of longitude 67°E. between the latitudes 12°N and 20°N. At first moving in a NNW direction most of them recurve to the west and cross the northern part of the sea ; but a few recurve in a NE'ly direction and move to the Sind or Kathiawar coast.

BAY OF BENGAL.—Storms are frequent and are mostly of moderate intensity and form north of the 16th parallel of latitude. They usually travel in W to NW'ly direction to the Orissa and Bengal coasts, and continue inland as depressions.

JULY.

ARABIAN SEA.—The number of storms markedly decreases in July, those that form being only of moderate intensity and confined to the NE of the sea. Their direction of movement is between W and NNW.

BAY OF BENGAL.—Same as in June.

AUGUST.

ARABIAN SEA.—The Arabian Sea is entirely free from cyclonic storms during August. The strong southwest monsoon winds that prevail may, however, at times reach gale force or even force 10 on the Beaufort scale.

BAY OF BENGAL.—Same as in June.

SEPTEMBER.

ARABIAN SEA.—Cyclonic storms are infrequent during this month in the Arabian Sea.

BAY OF BENGAL.—Storms are frequent in this month and form to the north of Lat. 14° N. They may be of moderate or violent force and move in any direction between W and NNE.

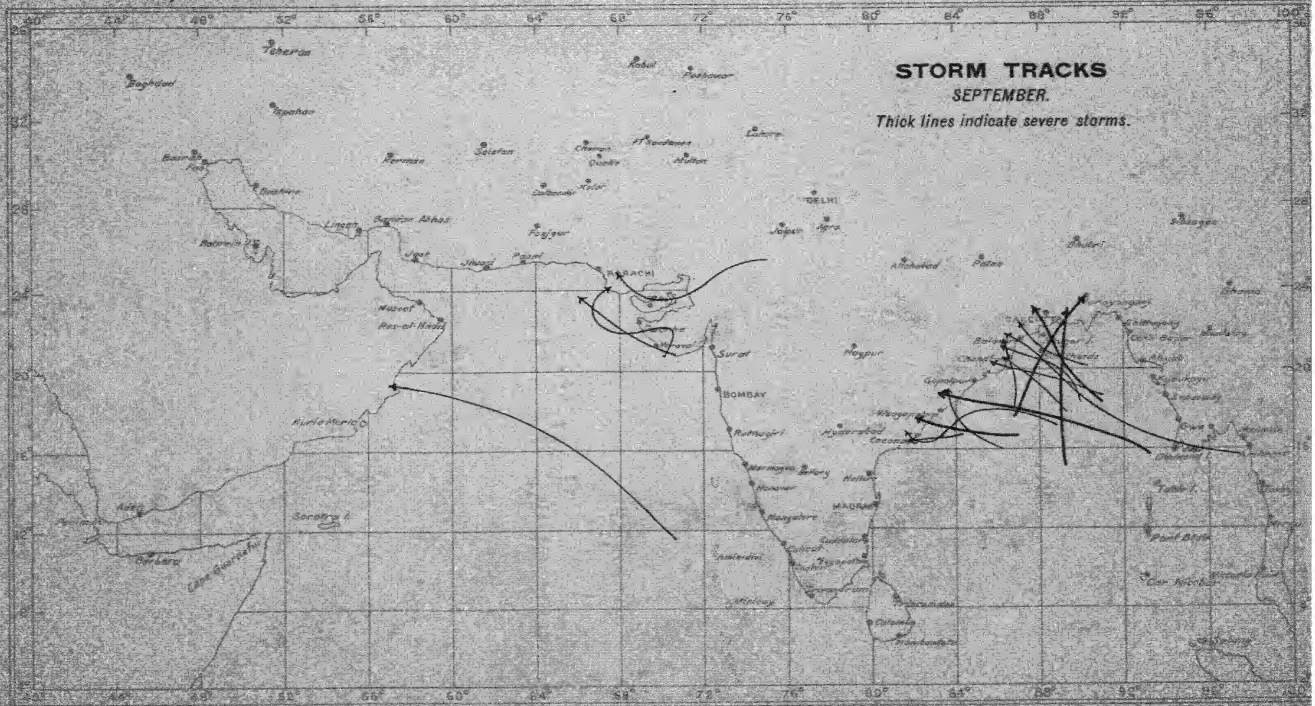

FIG. 17.

To face page 44.

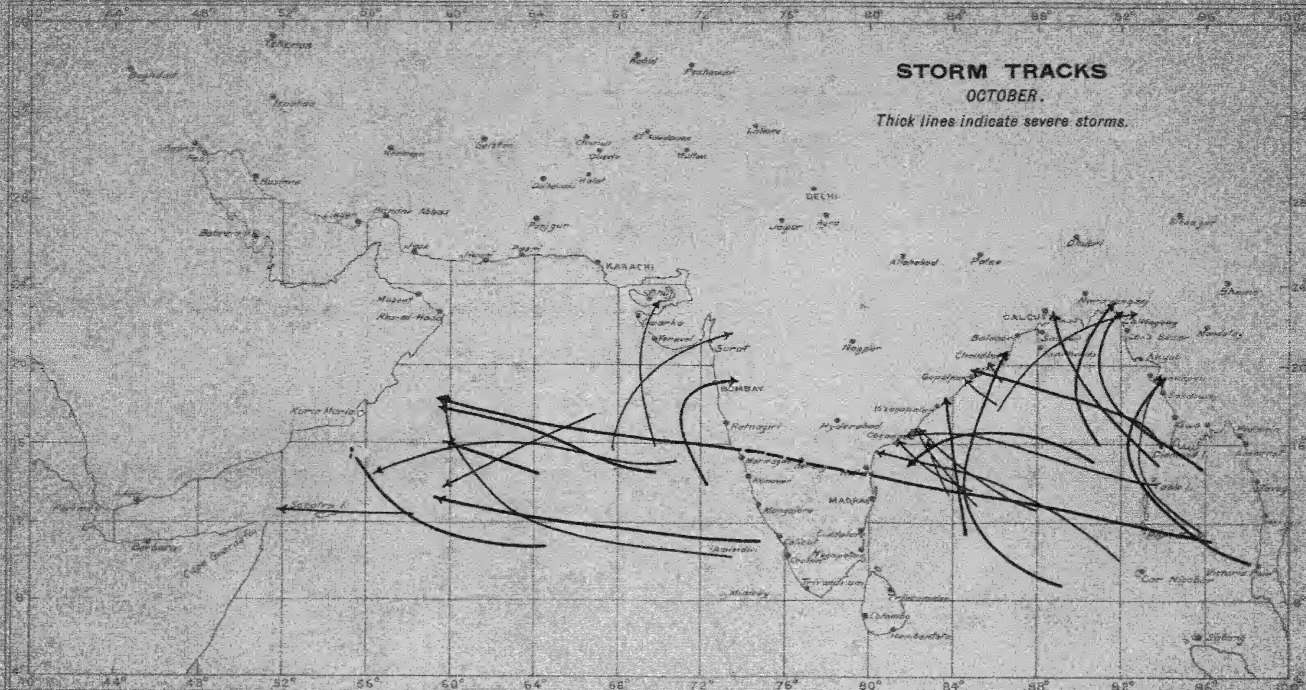
STORM TRACKS
OCTOBER.
Thick lines indicate severe storms.
KARACHI
DELHI
BOMBAY
CALCUTTA
MADRAS
Surat
Nagpur
Hyderabad
Patna
Allahabad
Lahore
Peshawar
Kabul
Jaipur
Agra
Muscat
Ras-al-Hadd
Socotra I.
Berbera
Cape Guardafui
Kuria Muria
Bandar Abbas
Basrah
Bushire
Teheran
Baghdad
Ispahan
Ratnagiri
Honovar
Mangalore
Calicut
Cochin
Trivandrum
Trincomalee
Colombo
Hambantota
Vizagapatam
Cocanada
Gopalpur
Chandbali
Balasore
Chittagong
Cox's Bazar
Akyab
Sandoway
Bassein
Rangoon
Victoria Point
Car Nicobar
Bhamo
Dhubri
44°
48°
52°
56°
60°
64°
68°
72°
76°
80°
84°
88°
92°
96°
100°

FIG. 18.

OCTOBER.

ARABIAN SEA.—Storms are of frequent occurrence in October and are generally of severe intensity. Those which enter the sea from the Bay of Bengal through the Indian Peninsula progress in a W by N direction to about the 58th meridian : while those which form in the eastern side of the Arabian Sea itself travel at first in a NNW direction and then recurve to the NE. Storms which keep below latitude 18°N move in a W to NW'ly direction.

BAY OF BENGAL.—Storms are most frequent in this month, and may form in any part of the Bay. They are generally severe and move in any direction between W and N, with a tendency to recurve to the NE at their later stages.

NOVEMBER.

ARABIAN SEA.—This is the month of maximum frequency for occurrence of storms which are of great intensity. They form between the 8th and 16th parallel of latitude eastward of 68th meridian or come through the Peninsula from the Bay of Bengal, and first travel northwestwards later recurving to the NE towards the Konkon and Kathiawar coasts. Cases are also known of storms having formed in the central Arabian Sea which travelled in a W to NNW'ly direction.

BAY OF BENGAL.—In this month storms are a little less frequent than in October and form in any part of the Bay south of the 16th parallel of latitude. They are generally very severe in intensity. The majority of storms forming between the 12th and 16th parallels at first move in a NW to N direction and then recurving to the NE advance towards the head of the Bay of Bengal. Storms forming south of the 12th parallel generally move in a W to NW direction towards the Madras coast.

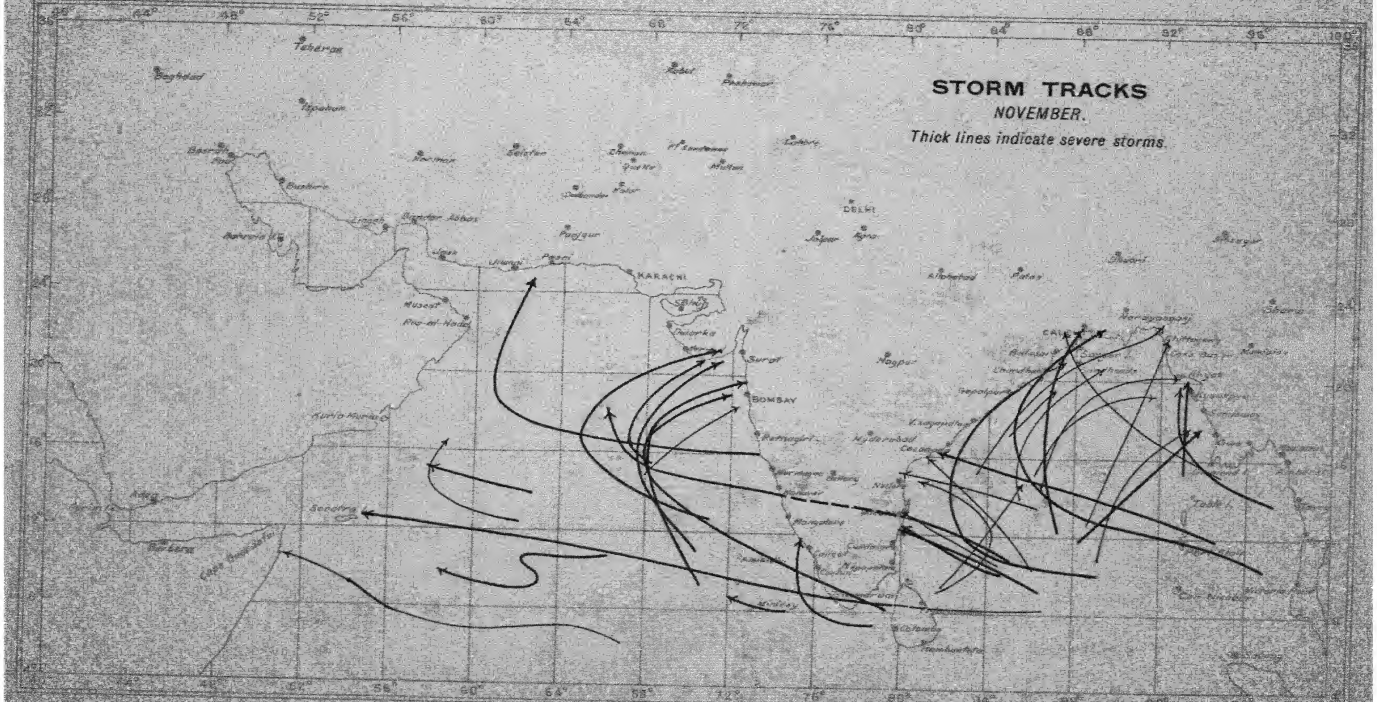

FIG. 19.

To face page 46.

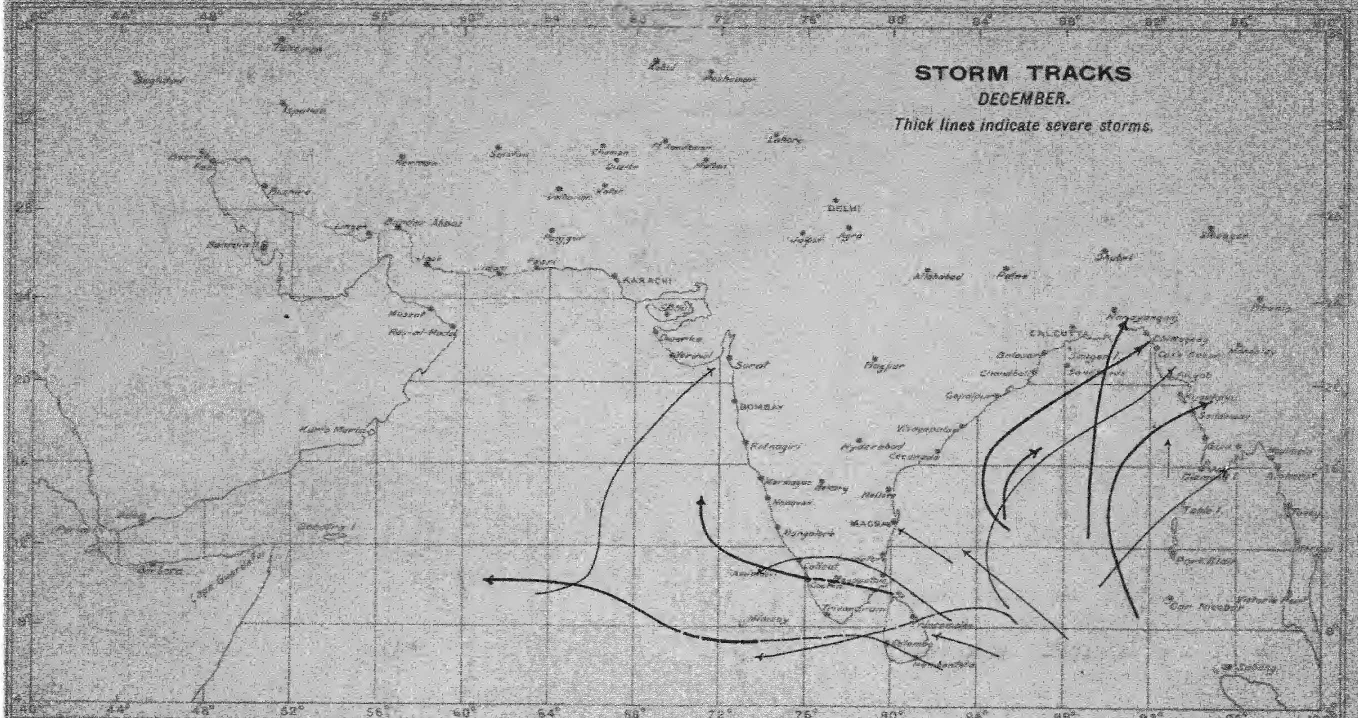
STORM TRACKS
DECEMBER.
Thick lines indicate severe storms.
KARACHI
DELHI
CALCUTTA
BOMBAY
MADRAS
Surat
Nagpur
Ratnagiri
Mangalore
Trivandrum
Colombo
Port Blair
Car Nicobar
Agra
Jaipur
Lahore
Patna
Allahabad
Muscat
Socotra I
Cape Guardafui

FIG. 20.

DECEMBER.

ARABIAN SEA.—The frequency of storms decreases in December. Most of them enter the sea from the Bay of Bengal, are severe and move generally towards W or WNW.

BAY OF BENGAL.—Storms are much less frequent in this month than in the preceding two months and form south of latitude 16°N. in the centre or SW portion of the Bay of Bengal. The former which are mostly severe move N'wards and then recurve to the NE and move to the head of the Bay or strike the Burma or Pegu coasts : while the latter move in a WNW direction towards the Madras coast.

CHAPTER VII.

WIRELESS BROADCASTS OF WEATHER BULLETINS AND SYNOPTIC METEOROLOGICAL DATA.

Under normal conditions, *weather Bulletins for shipping issued by the India Meteorological Department* are broadcast each day from coastal radio stations in India, Ceylon and Arabia to ships in the Arabian Sea and the Bay of Bengal. These weather bulletins describe briefly the position, development in intensity and probable movement of storms. The issues which are ordinarily twice daily, are increased in disturbed or stormy weather to three or six times a day. When necessary further messages are broadcast at non-routine times also. During disturbed weather these broadcasts give information about specific areas and in order to do this conveniently and concisely the Bay of Bengal and the Arabian Sea have been divided into different areas, to which names have been assigned as shown in *Fig. 21.*

It must always be remembered that the warnings by wireless telegraphy issued by the India Meteorological Department can only be effective if reliable information from the vicinity of storms is available along with the land observations at the Weather Office at Poona for the Arabian Sea disturbances and at Alipore, Calcutta, for the Bay of Bengal disturbances, hence the great need for weather reports by wireless from ships to the shore stations.

The arrangements made for broadcasting meteorological bulletins to ships at sea and for ships to transmit by wireless their weather messages to the coastal radio stations are fully explained in the publication named " Weather Codes for Ships in Indian Waters " issued by the India Meteorological Department.

Ships equipped with wireless can now (under peace-time conditions) prepare their own weather charts from the data of weather observations made at Indian coastal and inland stations and on ships in Indian waters which are collected by the India Meteorological Department and broadcast from the coastal Radio Stations. The department's pamphlet " Weather Broadcasts to Ships (1939) " gives detailed information about them.

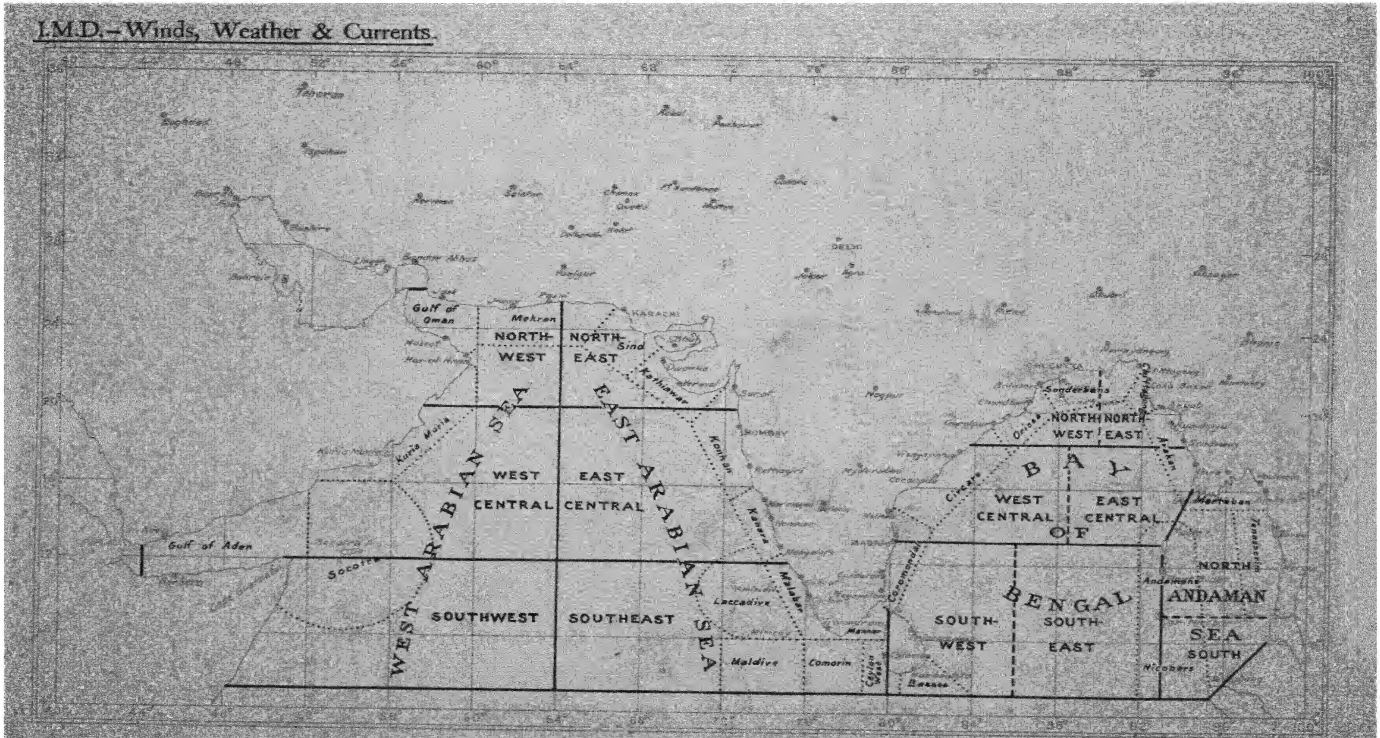

FIG. 21. COASTS AND REGIONS MENTIONED IN WEATHER BULLETINS.

To face page 48.

I.M.D.–Winds, Weather & Currents.

INDIAN & BURMAN PORTS

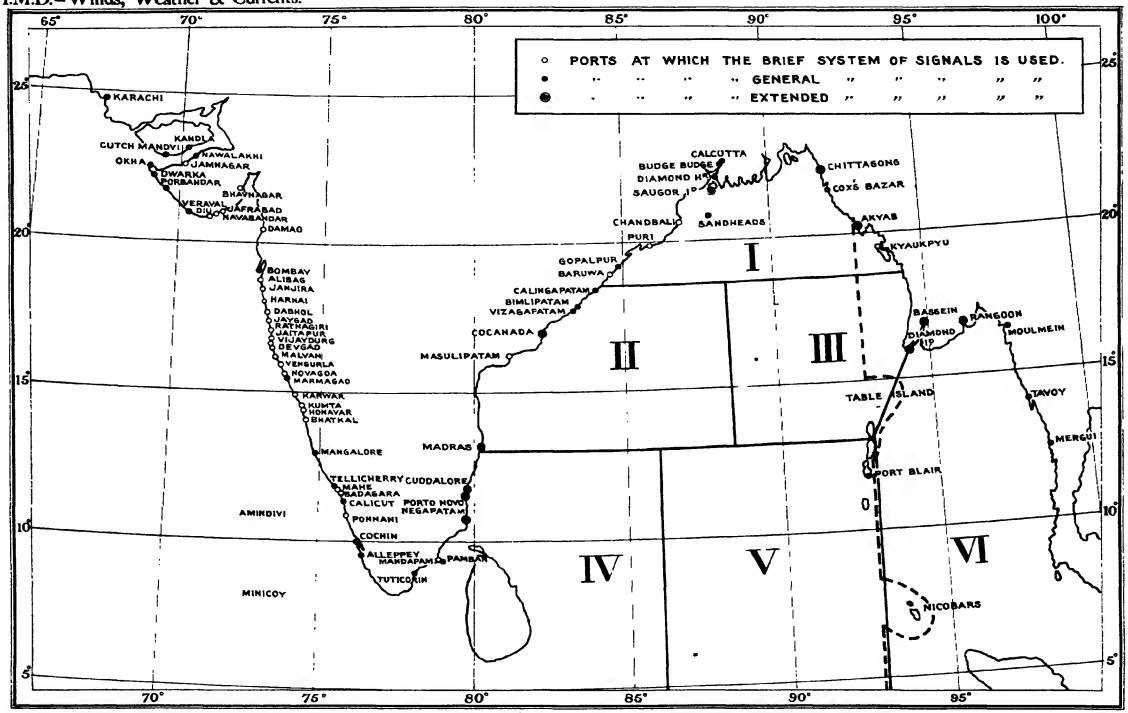

FIG. 22.

Warnings for the area east of the dotted line and to ports on the Burman coast are issued by the Burma Meteorological Department.

G.P.I. POONA 1942

CHAPTER VIII.

VISUAL STORM WARNING SIGNALS IN USE AT INDIAN PORTS.

Whenever a storm or a disturbance exists in the Indian Seas, suitable visual warning signals are hoisted at such ports on the coasts as are likely to be affected by the disturbance. The meaning of any given signal is the same throughout the Indian coast.

The Meteorological Department keeps Port Officers informed of the latest information with respect to all disturbances, and ships' officers should apply to them for information to supplement the storm signals.

The Poona Meteorological Office is the warning centre for the Arabian Sea and the Calcutta Meteorological Office for the Bay of Bengal for the area west of the dotted line in *Fig. 22*. Warnings for the area east of the dotted line and to ports on the Burman coast are issued by the Burma Meteorological Department.

The present system of storm warning signals may be shortly described as follows :—

(*a*) A general system consisting of eleven signals.

(*b*) A brief system consisting of four only of the above signals. This system is used at smaller ports frequented mainly by small boats engaged in local traffic.

(*c*) An extended system which in addition to the signals of the general system, includes signals to indicate the position of the disturbance. The system is in use at only certain stations in the Bay of Bengal.

The Arabian Sea and Bay of Bengal ports in which one or other of these systems of signals is in force are given in *Tables* IV and V and are also given in *Fig. 22*.

Table IV.

ARABIAN SEA PORTS.

General System.	*Brief System.*
Karachi.	Jamnagar.
Cutch Mandvi.	Diu.
Kandla.	Navabandar.
Nawalakhi.	Jafrabad.
Okha.	Bhavnagar.
Dwarka.	Damao.
Porbandar.	Alibag.
Veraval.	Janjira.
Bombay	Harnai.
Marmagao.	Dabhol.
Mangalore.*	Jayagad.
Tellicherry.†	Ratnagiri.
Calicut.*	Jaitapur.
Cochin.	Vijaydurg.
Alleppey.‡	Devgad.
	Malvan.
	Vengurla.
	Nova Goa.
	Karwar.
	Kumta.
	Honavar.
	Bhatkal.
	Mahé.
	Badagara.
	Ponnani.

* On receipt of warnings, the Port Officers at *Mangalore* and *Calicut* transmit suitable warnings to the following smaller ports within their respective jurisdiction:

The Port Officer, *Mangalore*, to Kasargod, Mulky, Malpe, Hangar Kotta, Kundapur and Baindur.

The Port Officer, *Calicut*, to Quilandi, Azhikkal and Kallayi.

† This port transmits storm warnings to Cannanore.

‡ This port transmits information to the ports Quilon, Trivandrum and Colachel, which are under its jurisdiction.

Table V.

BAY OF BENGAL PORTS.

Extended System.	*General System.*	*Brief System.*
Rangoon.*	Port Blair.	Chandbali.
Diamond Island. *	Mergui.*	Puri.
Akyab.*	Moulmein.*	Baruwa.
Chittagong.	Cox's Bazar.	Masulipatam.
Saugor Island.	Calcutta.	
Cocanada.	Budge Budge.	
Madras.	Diamond Harbour.	
Cuddalore.	Gopalpur.	
Porto Novo.	Calingapatam.	
Negapatam.	Bimlipatam.	
	Vizagapatam.	
	Pamban.	
	Tuticorin.	

The following receive information *but hoist no signals* :—

Bassein.*	Tavoy.*	Mandapam.
	Sandheads.	Kyaukpyu.*

(a) General System.

1. *Distant Signals.*—To indicate *danger to ships* after they have left the harbour.

	Day.	Night.
I.—Cautionary.—There is a region of squally weather in which storm may be forming.		

Note.—This signal will be hoisted at ports so situated with reference to the disturbed weather that a ship leaving the port might run into danger during its voyage. It will also be hoisted at Arabian Sea ports when a disturbance which may develop into a cyclone after entering the Arabian Sea, is crossing the peninsula.

* Storm warnings to these ports are issued by the Burma Meteorological Department.

Day. Night.

II.—*Warning.*—A storm has formed.

Note.—This signal will be hoisted when there is no immediate danger of the port itself being affected, but ships leaving the port might run into the storm.

Note.—In the night signals ○ represents a white light and ● a red light.

2. *Local Signals.*—To indicate that the port and ships in it are threatened.

Day. Night.

III.—*Cautionary.*—The port is threatend by squally weather.

IV.—*Warning.*—The port is threatened by a storm, but it does not appear that the danger is as yet sufficiently great to justify extreme measures of precaution.

V.—*Danger.*—The port will experience severe weather from a storm of slight or moderate intensity, that is expected to cross the coast to the south of the port (or to the east in the case of Veraval, the Hoogly ports, Diamond Island, Bassein, Rangoon and Port Blair).

VI.—*Danger.*—The port will experience severe weather from a storm of slight or moderate intensity that is expected to cross the coast to the north of the port (or to the west in the case of the Hoogly ports, Chittagong, Rangoon, Moulmein, Karachi and Port Blair).

Day. Night.

VII.—Danger.—The port will experience severe weather from a storm of slight or moderate intensity that is expected to cross over or near to the port.

VIII.—Great Danger.—The port will experience severe weather from a storm of great intensity that is expected to cross the coast to the south of the port (or to the east in the case of Veraval, the Hoogly ports, Diamond Island, Bassein, Rangoon and Port Blair).

IX.—Great Danger.—The port will experience severe weather from a storm of great intensity that is expected to cross the coast to the north of the port (or to the west in the case of the Hoogly ports, Chittagong, Rangoon, Moulmein, Karachi and Port Blair).

X.—Great Danger.—The port will experience severe weather from a storm of great intensity that is expected to cross over or near the port.

XI.—Failure of Communications.—Communication with the meteorological warning centre has broken down and the local officer considers that there is danger of bad weather.

(b) BRIEF SYSTEM.

In the brief system, only the following four signals will be hoisted, but the port officers will be kept informed of the progress of bad weather for the general information of shipping. The meanings of the signals are the same as those given on pages 52 and 53, but for easier understanding, are translated below into non-technical language.

Name of Signal.	Sign of Signal.		Meaning of Signal.	
	Day.	Night.	When weather is deteriorating.	When weather is improving.
III. Local Cautionary.			You will have squally weather here, and you *must* also look out for development, for this weather may develop into a gale in a day or two. Be on the alert.	The weather is moderating but squally weather is still likely. Be careful.
IV. Local Warning.			There is a gale threatening you here. The sea hereabouts is likely to be unsafe for sailing boats and small coasting steamers. Take shelter.	A gale is still threatening you and the sea is still unsafe for sailing boats and small coasting steamers; continue to be in shelter.
VII. Danger.			You are going to have gales and heavy seas. Protect your boat immediately.	Hurricanes unlikely but still expect gales and heavy seas. Don't take your boat out.
X. Great Danger.			Look out for a hurricane wind and mountainous sea.	

(c) EXTENDED SYSTEM OF SIGNALS FOR THE BAY OF BENGAL.

In the Bay of Bengal it is possible to locate the area of bad weather with some degree of certainty even when it is far from the coast. Therefore in order to give information regarding weather in the Bay the following arrangements have been made :—

(1) if the port itself is threatened the appropriate local signal of the " general system " will be hoisted ;

(2) if there be an area of squally weather or a storm that does not threaten the port, the " distant cautionary " or " distant warning " signal of the

" general system " will be hoisted ; and additional signs will be hoisted under these to indicate the position of the disturbance in the Bay. For this purpose the Bay has been divided into six sections, as shown on the accompanying map (*see Fig. 22*) and the following signs have been allotted to each of the sections :—

Division I II III IV V VI

Signal 

Thus if there is squally weather in section V of the Bay the signal  would be hoisted at the various ports ; and if a storm has formed in section II the signal  would be hoisted at all ports which were not directly threatened ; as already stated the ports threatened would hoist one or other of the local signals.

The Meteorological Department will endeavour to keep the number of locality signals on each hoist as few as possible and generally only the number of the section in which the centre of the storm is situated will be given. If, however, the centre of the storm is near the boundary of a section, two locality signals will be given, the first indicating the section in which the centre is supposed to be and the second the neighbouring section near to which it is. In the event of a storm centre being near to the angles where three sections meet, three locality signals will be hoisted. The first will give the section in which the storm is supposed to be, the second the nearest adjoining section and the third the remaining section.

Examples.

Storm centre.	Locality signals.
Lat. 16°N. Long. 86°E. . . .	II.
Lat. 16°N. Long. 88°E. . . .	II and III.
Lat. 16°N. Long. 89°E. . . .	III and II.
Lat. 18°N. Long. 87½°E. . . .	II, I and III.
Lat. 19°N. Long. 89½°E. . . .	I, III and II.

The following notes may facilitate the identification of the signals :—

Day Signals.

(*a*) All *distant* signals, and only distant signals, have a *bar* either horizontal or vertical as their upper member.

(*b*) All *local* signals, and only local signals, have a *triangle* or a *double triangle* as their upper member.

(*c*) *Cautionary* and *Warning* signals (distant and local) consist of only *one* shape, except at certain ports in the Bay of Bengal where additional shapes are used to indicate the locality of the disturbances.

(*d*) *Danger* signals consist of *two* shapes the lower of which indicates the severity of the storm and the upper where the storm is expected to cross the coast.

(*e*) A *diamond* as the lower member of a danger signal indicates *danger* and a *vertical bar great danger.*

(*f*) The point of the triangle of a danger signal indicates where the storm is expected to cross the coast—the point *down* indicates the *south*, the *point up north*, and the *double triangle*, with its points in the middle indicates *at or near* to the port itself.

Night Signals.

(*g*) *Failure of communication* signal consists of *one* lamp.

(*h*) *Cautionary* and *Warning* signals consist of *two* lamps.

(*i*) *Danger* signals consist of *three* lamps.

(*j*) The *intensity* of the danger is indicated by the *number of red* lamps ; in the danger signals there is only one red lamp and in the great danger two red lamps.

(*k*) The position of the red lamps in a danger signal indicates where the storm is likely to cross the coast. When the storm is expected to pass to the *north*, the red lamp or lamps are in the *upper* part of the signal ; when to the south, they are in the *lower* part of the signal. If the red lamps are symmetrical about the middle the storm is expected to pass over the port itself.

APPENDIX I.

A note on navigation in the Bay of Bengal during disturbed weather.

When running up the Bay of Bengal with a strong southwest wind occasional squalls and rain, and a slowly-falling barometer, are experienced, bad weather prevails somewhere to the northward.

Between the beginning of June and the middle of September the storm centres are generally northward of Lat. 16°N, and in July or August still further northward, and a sailing vessel or low powered steamship should steer eastward and take advantage of the southerly and south-westerly winds on the eastern side of the storm as it moves northwestward. But should the weather get rapidly bad, and the barometer continue to fall, then heave-to and determine the position with regard to the movement of the storm before proceeding.

In May, October, or November the storms travel in some direction from west, through north, to northeast and then the course of a storm should be definitely ascertained before any attempt is made to round its eastern side, because if it is moving northeastward such a procedure would be attended with danger.

When leaving the Hoogly from June to September notice of the approach of a cyclonic storm or of the existence of a storm in the northern part of the Bay, is given by easterly winds and a falling barometer, or by the storm signals at the telegraph stations. In July or August the storm will probably be of moderate force, although not invariably so, but in June and September some most violent cyclones have visited the coasts of Bengal and Orissa. As a vessel sailing southward would most likely run into the storm, the river should not be left until the weather has moderated.

In May, October, or November a squally easterly or northeasterly wind driving low, long-drawn masses of cloud before it, or a strong westerly set in the sea at the head of the Bay of Bengal, indicate that a cyclonic storm is in the northern part of the Bay, and a vessel should not proceed southward until finer weather prevails. But in these months a cyclonic storm may be far down the Bay, and at the Hoogly river, or other port at the head of the Bay, there may be every appearance of fine weather. With these conditions, on the first indications of the coming storm the changes of the wind and barometer should be carefully watched, and the course of the storm, if possible, be determined. If in the righthand

semicircle, the vessel should be hove-to on the starboard tack until the storm has passed ; and if undoubtedly in the left-hand semicircle, should heave-to on the port tack if the wind is eastward of north, or run southward, keeping the wind on the starboard quarter, when the wind is north, or westward of north.

Vessels lying in the roadsteads of the Coromandel coast on the approach of a cyclonic storm usually run southward round the south-western quadrant ; this is probably the only course open to sailing vessels ; but full-powered steamers leaving while the centre is still more than 100 miles distant, and the wind between north and northnorthwest, might if necessary proceed northeastward, if it has been ascertained that the storm is not moving northwestward or northward of that.

Vessels leaving Rangoon or Moulmein, and encountering strong northeasterly winds, with a falling barometer, denoting the existence of a cyclonic storm eastward of the Andaman Islands, should delay their departure until the storm has passed, which is indicated by a rising barometer, and the wind shifting to east or southward of east.

The following instructions have been approved by the Port Officer, Calcutta for the security of shipping in the approaches to the port of Calcutta :

Danger Signal V indicates that a storm of slight or moderate severity will probably cross the coast to the east of Saugor Island and west of Chittagong. Vessels may proceed to sea if the height of the barometer and state of the sea and weather are such as to lead masters and pilots to infer that there is no danger. The wind at the mouth of the Hoogly will probably haul from northeast through north to northwest or west.

Danger Signal VI indicates that a storm of slight or moderate severity will probably cross the coast to the west of Saugor Island and north of False Point. The wind at the mouth of the Hoogly will probably veer from northeast through east to southeast or south. As these easterly winds will raise a heavy swell and produce a strong westerly set in the channel at the Sandheads, it is advisable that none but fast steamers in light trim should put to sea, and those only if the weather appearances and state of the sea are not too unfavourable.

Danger Signal VII indicates the approach towards Saugor roads of a storm of slight or moderate intensity. It is advisable that no vessels except fast steamers in light trim should put to sea until the wind direction and force, the state of weather and sea and the rise of the barometer

indicate that the storm has either broken up or passed inland. It should be remembered that cyclonic storms of small extent in the Bay of Bengal sometimes blow with hurricane force and raise a high sea near their centres.

Great Danger Signal VIII indicates that a storm of great intensity will cross the coast to the east of Saugor Island and west of Chittagong. It is advisable that sailing vessels, with or without steam, and deep-laden or slow-steaming steam-vessels, should not proceed to sea, but remain in the river till the storm has reached the coast and passed inland. The wind at the mouth of the Hoogly will probably haul from northeast through north to northwest or west.

Great Danger Signal IX indicates that a storm of great intensity will cross the coast to the west of Saugor Island and north of False Point. No vessels should go to sea, and masters and pilots of vessels outward-bound should be guided by the appearance of the weather and height of the barometer in deciding whether it is advisable to proceed below Diamond Harbour or Mud Point. The wind at the mouth of the Hoogly will probably veer from northeast through east to southeast or south.

Great Danger Signal X indicates the approach of a storm of great intensity towards the mouth of the Hoogly and Calcutta. Masters and pilots in charge of vessels are cautioned not to put to sea from Saugor Island, not to proceed down from Diamond Harbour, and they should make their vessels as snug and secure as possible. The masters of vessels in the port should take the special precautions for safety laid down in the port rules.

There will probably be a storm-wave, and it should be carefully remembered that its height and destructive effect will depend quite as much upon the state and character of the tide when the cyclonic centre reaches the coast, as upon the depression at the centre, or the intensity and extent of the storm.

APPENDIX II.

Tables of climatological data of 14 coastal Indian and Burman stations : Pasni, Karachi, Veraval, Bombay, Marmagao, Mangalore, Cochin, Colombo, Madras, Vizagapatam, Calcutta, Akyab, Rangoon and Victoria Point.

Pasni. Lat. 25° 16′N. Long. 63° 28′ E. Height above M. S. L. 10 ft.

Table compiled from 9 to 10 years' observations between 1911 and 1920.

Month.	Pressure reduced to 32° F & Lat. 25°.		Air temperature.					Relative humidity.	Cloud.	Rain.			Wind.		
	Mean.		Mean. 8 hrs.	Mean daily.		Extreme.				Mean monthly total.	Mean number of days.	Maximum in 24 hours.	Mean daily velocity in miles per hour.	Most frequent direction.	
	8 hrs.	Daily range.	Dry bulb.	Max.	Min.	Max.	Min.	Mean.	8 hrs.					8 hrs.	17 hrs. I.S.T.*
	in.	in.	°F	°F	°F	°F	°F	%		in.		in.			
January	30·08	..	61	77	55	89	43	82	2·6	2·3	2	4·5	4	NNW	SW
February	30·02	..	62	77	55	95	31	80	2·7	1·7	2	3·2	5	WNW	WSW
March	29·92	..	68	84	61	99	47	81	2·3	0·9	1	3·4	5	WNW	WSW
April	29 82	..	75	89	67	103	50	82	1·9	0·4	0·6	1·0	6	WNW	WSW
May	29·69	..	81	94	74	110	61	83	2·5	0·0	0·1	0·3	7	WNW	WSW
June	29·52	..	85	95	78	115	68	83	3·6	0·7	0·4	5·0	7	W	WSW
July	29·51	..	83	92	77	103	69	85	5·5	0·1	0·4	0·4	6	WSW	SW
August	29·58	..	81	89	75	98	64	86	6·8	0·3	0·4	1·7	5	WSW	SW
September	29 73	..	78	90	72	104	60	86	4·1	0 0	0·0	0·0	6	W	WSW
October	29·88	..	75	91	65	105	51	73	1·8	0·0	0 0	0·1	5	WNW	SW
November	29·99	..	68	85	59	99	37	68	1·0	0·1	0·2	0·2	4	NNW	SW
December	30·06	..	62	78	54	90	40	71	1·9	0·5	1	0·9	4	NNW	SSW
Means	29·82	..	73	87	66	..	.	80	3·1	..	..	..	5	..	..
Totals	..	..	..	..	.	..	..	..	.	7 0	8	..	..	..	..
Extreme values ..	..	..	..	..	.	115	31	..	.	.	..	5·0	..	..	..
No. of years of observations	10	..	10	10	9	10	9	10	10	10	10	10	10	10	7

*1. Based on data for 7 years (1933—39).
2. Hour of observation for 1933 to June 1934 is 14 hrs. G. M. T.
3. Hour of observation for July 1934 to December 1937 is 12 hrs. G. M. T
4. Hour of observation for 1938 and 1939 is 17 hrs. I. S. T.

Karachi.—Lat. 24° 47′ 37″N. Long. 66° 58′ 35″ E. Height above M. S. L. 13 ft.

Table compiled from 13 to 43 years' observations between 1878 and 1920.

Month.	Pressure reduced to 32° F & Lat. 45°.		Air temperature.					Relative humidity.	Cloud.	Rain.			Wind.		
	Mean.		Mean 8 hrs.	Mean daily.		Extreme				Mean monthly total	Mean number of days.	Maximum in 24 hours.	Mean daily velocity in miles per hour.	Most frequent direction.	
	8 hrs.	Daily range.	Dry bulb.	Max.	Min.	Max.	Min	Mean	8 hrs.					8 hrs.	17 hrs. I.S.T.*
	in.	in.	°F	°F	°F	°F	°F	%		in.		in.			
January	30·06	·11	59	76	58	89	40	61	2·6	0·5	1	1·6	6	NNE	SW
February	30·00	·11	63	78	61	93	43	65	2 3	0·4	1	1·0	7	NNE	WSW
March	29·91	·10	72	82	68	106	47	70	2·4	0·3	0·7	1·9	8	WNW	WSW
April	29 80	·09	79	85	74	111	57	78	2·6	0·2	0·2	4·1	10	WSW	WSW
May	29·69	·09	84	89	79	118	65	80	3·3	0 1	0·1	1·2	12	WSW	SW
June	29·53	·07	86	91	83	114	68	80	5·4	0·9	0·6	7·2	13	WSW	SW
July	29·50	·07	84	88	81	110	73	83	7·3	2·9	2	6·1	13	WSW	SW
August	29·57	·07	81	85	78	99	73	85	7·5	1·7	2	4·2	12	WSW	WSW
September	29·72	·08	80	86	77	106	69	82	4 8	0 4	0·6	2·1	10	WSW	WSW
October	29·87	·09	78	88	73	108	57	72	1·6	0 0	0·0	0·2	7	W	WSW
November	29·99	·10	71	85	67	100	48	61	1 1	0·0	0·1	0·9	5	NNE	WSW
December	30·06	·11	62	78	59	91	39	57	1·9	0 1	0·5	0·9	6	NNE	SW
Means	29·81	·09	75	84	71	..	.	73	3·6	.	..	..	9	..	..
Totals	..	..	..	.	..	..	..	.	..	7·6	9	..	..	..	..
Extreme values ..	..	..	..	..	..	118	39	..	..	..	..	7·2	..	..	..
No. of years of observations.	32	..	32	13	13	43	43	13	32	43	43	43	43	22	7

* Based on data for 7 years (1933—39).

Veraval.—Lat. 20° 53′N. Long. 70° 26′ E. Height above M. S. L. 19 ft.

Table compiled from 20 to 31 years' observations between 1890 and 1920.

Month.	Pressure reduced to 32° F & Lat. 45°.		Air temperature.					Relative humidity.	Cloud.	Rain.			Wind.		
	Mean.		Mean 8 hrs.	Mean daily.		Extreme.				Mean monthly total.	Mean number of days.	Maximum in 24 hours.	Mean daily velocity in miles per hour.	Most frequent direction.	
	8 hrs.	Daily range.	Dry bulb.	Max.	Min.	Max.	Min.	Mean.	8 hrs.					8 hrs.	17 hrs. I.S.T *
	in.	in.	°F	°F	°F	°F	°F	%		in.		in.			
January	29·99	..	65	82	60	94	40	54	1·4	0·0	0·1	0·3	5	NNE	WNW
February	29·95	..	66	81	61	96	40	59	1·4	0·1	0·2	0·6	6	NNE	WNW
March	29·89	..	73	85	65	105	49	65	1·5	0·1	0·2	0·7	7	NNW	WNW
April	29·82	.	79	86	72	105	57	74	2·2	0·0	0·0	0·0	7	NNW	WNW
May	29·75	..	82	86	79	104	66	82	3·2	0·3	0·4	4·9	8	W	W
June	29·61	..	83	86	81	93	74	85	6·0	4·5	4	7·8	10	WSW	WSW
July	29·58	..	81	84	80	93	70	88	8·0	6·9	9	5·7	12	WSW	WSW
August	29·66	.	80	82	78	89	73	89	8·1	3·8	6	7·7	10	WSW	WSW
September	29·76	..	79	83	77	98	69	86	5·3	2·3	4	5·4	6	WNW	WNW
October	29·86	..	79	89	73	102	61	69	2·2	0·7	0·7	6·8	5	NNW	WNW
November	29·93	.	75	89	68	99	57	54	1·3	0·2	0·1	3·5	5	NNE	WSW
December	29·98		68	84	62	95	46	50	1·5	0·1	0·2	1·0	4	NNE	WNW
Means .. .	29·81	.	76	85	71	..	..	71	3·5	..	..	..	7	..	..
Totals	..	.	..	..	..	..	..	..	..	18·8	25	..	..	..	..
Extreme values ..	..	..	..	..	..	105	40	..	..	..	..	7·8	..	.	..
No. of years of observations.	31	..	31	31	31	30	30	31	31	31	31	30	31	20	7

* Based on 7 years' data (1933—39).

M41DGofOb

Bombay.—Lat. 18° 54′N Long. 72° 49′E. Height above M.S.L. 37 ft.

Table compiled from 12 to 51 years' observations between 1866 and 1920.

Month.	Pressure reduced to 32° F & Lat. 45°.		Air temperature.					Relative humidity.	Cloud.	Rain.			Wind.		
	Mean.		Mean 8 hrs.	Mean daily.		Extreme.				Mean monthly total.	Mean number of days.	Maximum in 24 hours.	Mean daily velocity in miles per hour.	Most frequent direction.	
	8 hrs.	Daily range.	Dry bulb.	Max.	Min.	Max.	Min.	Mean.	8 hrs.					8 hrs.	17 hrs. I.S.T.*
	in.	in.	°F	°F	°F	°F	°F	%		in.		in.			
January	29·95	·12	71	83	67	92	56	73	1·5	0·1	0·2	1·6	9	ENE	NNW
February	29·92	·12	72	83	67	95	56	71	1·3	0·1	0·2	1·6	10	ENE	NW
March	29·87	·12	77	86	72	97	62	74	1·8	0·1	0·1	1·3	10	NNE	NW
April	29·81	·12	81	89	76	100	68	75	3·1	0·1	0·1	1·1	10	Var.	WNW
May	29·77	·10	84	91	79	96	73	74	4·3	0·8	0·8	3·5	9	Ver.	WNW
June	29·64	·08	83	88	78	99	73	82	7·5	18·3	14	16·1	13	WSW	W
July	29·63	·07	81	85	77	99	73	86	8·8	24·3	21	10·0	17	W	W
August	29·69	·07	80	85	76	88	72	86	8·8	13·8	19	11·3	14	W	W
September	29·77	·09	79	85	75	91	71	87	7·2	10·5	13	7·8	10	Var.	WNW
October	29·83	·11	80	89	75	95	70	82	3·9	2·2	3	5·9	8	ENE	NW
November	29·90	·11	77	89	72	96	64	74	2·0	0·4	0·7	2·5	9	ENE	NW
December	29·94	·12	73	86	69	91	56	72	1·6	0·1	0·1	1·0	9	ENE	NW
Means	29·81	·10	78	87	74	..	..	78	4·3	..	..	..	11	..	..
Totals	..	.	..	..	.	..	..	..	..	70·6	73	..	..	..	..
Extreme values	..	.	.	..	..	100	56	..	..	..	..	16·1	..	..	..
No. of years of observations.	32	.	32	43	43	43	43	32	32	43	43	43	51	12	7

* Based on data for 7 years (1933—39).

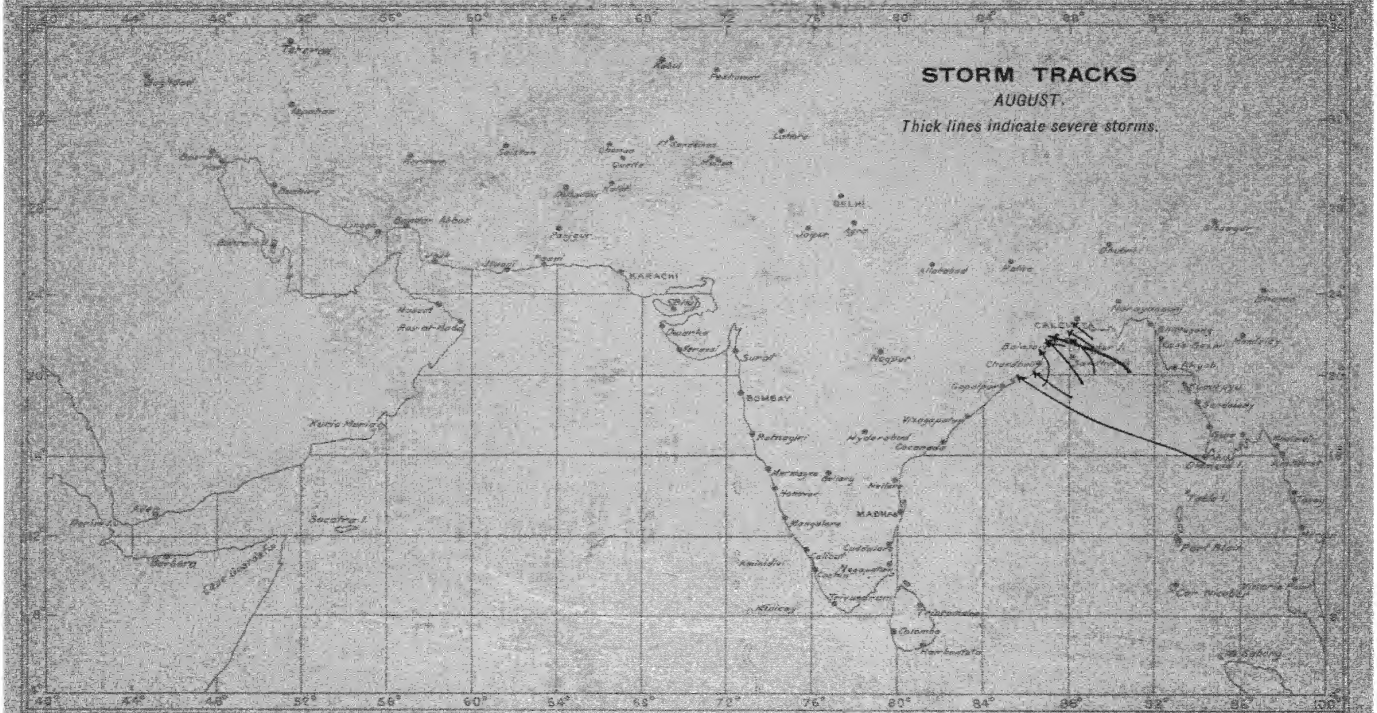
STORM TRACKS
AUGUST
Thick lines indicate severe storms.
KARACHI
BOMBAY
MADRAS
CALCUTTA
DELHI

FIG. 16.

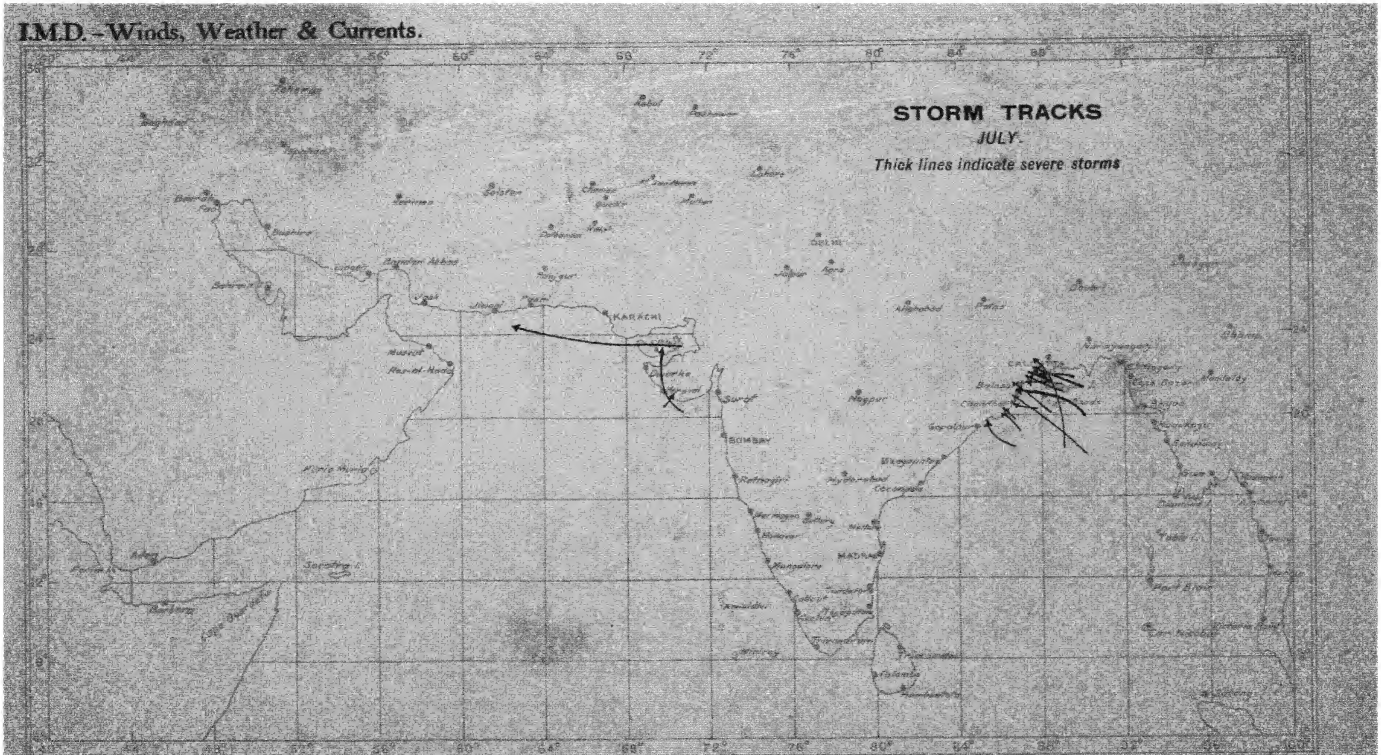

FIG. 15.

To face page 42.

Marmagao.—Lat. 15° 25′ N. Long. 73° 47′ E. Height above M. S. L. 60 ft.

Table compiled from 20 to 30 years' observations between 1890 and 1920.

Month.	Pressure reduced to 32° F & Lat. 45°.		Air temperature.					Relative humidity.	Cloud.	Rain.			Wind.		
	Mean.		Mean. 8 hrs.	Mean daily.		Extreme.				Mean monthly total.	Mean number of days.	Maximum in 24 hours	Mean daily velocity in miles per hour.	Most frequent direction.	
	8 hrs.	Daily range.	Dry bulb.	Max.	Min	Max.	Min.	Mean.	8 hrs.					8 hrs.	17 hrs. I. S. T.*
	in.	in.	°F	°F	°F	°F	°F	%		in.		in.			
January	29·90	.	72	85	70	92	60	82	1·6	0·0	0	0·6	6	E	W
February	29·87	.	73	85	71	93	62	83	1·5	0·1	0·1	1·1	6	ENE	WNW
March	29·83		79	87	75	95	62	79	2·5	0·0	0·1	0·3	7	NNE	WNW
April	29·78	.	83	89	79	96	68	75	4·1	0·7	0·9	4·6	7	NNW	WNW
May	29·75	..	85	90	81	95	72	76	5·3	2·6	3	12·1	7	NNW	WNW
June	29·67	..	81	87	77	95	71	87	7·8	29·6	21	11·7	8	W	WSW
July	29·68	..	80	84	76	89	71	90	8·5	31·2	25	10·6	9	W	W
August	29·73	.	79	83	76	88	71	91	8·0	15·9	23	7·7	8	W	W
September	29·77	..	78	83	75	88	71	92	6·9	9·5	15	5·6	5	Var.	WNW
October	29·81	..	78	85	75	94	69	90	5·1	3·8	6	6·4	4	ENE	WNW
November	29·85	..	76	86	73	93	64	81	3·0	1·3	2	2·9	5	ENE	W
December	29·89	..	73	85	70	92	61	77	1·9	0·2	0·4	2·0	6	ENE	WSW
Means	29·79	..	78	86	75	..	..	84	4·7	..	..	..	6	..	..
Totals	..	..	..	..	..	..	..	..	..	94·9	96	..	..	..	..
Extreme values	..	.	..	..	..	96	60	..	..	..	..	12·1	..	..	..
No. of years of observations.	30	..	30	30	29	30	29	30	30	30	30	30	30	20	2

* Based on data for 2 years (1938-39).

Mangalore. Lat. 12° 52′ N. Long. 74° 51′ E. Height above M. S. L. 72 ft.

Table compiled from 11 to 42 years' observations between 1879 and 1920.

Month.	Pressure reduced to 32° F & Lat. 45°.		Air temperature.					Relative humidity.	Cloud.	Rain.			Wind.		
	Mean.		Mean 8 hrs.	Mean daily.		Extreme.				Mean monthly total.	Mean number of days.	Maximum in 24 hours.	Mean daily velocity in miles per hour.	Most frequent direction.	
	8 hrs.	Daily range.	Dry bulb.	Max.	Min.	Max.	Min.	Mean.	8 hrs.					8 hrs.	17 hrs. I. S. T.*
	in.	in.	°F	°F	°F	°F	°F	%		in.		in.			
January	29·87	·12	75	89	70	95	61	66	2·1	0·1	0·1	1·0	3	E	WNW
February	29·85	·13	77	89	72	100	62	73	2·1	0·1	0·1	1·4	3	E	NW
March	29·82	·13	81	90	75	99	65	72	2·0	0·1	0·2	0·8	3	ENE	NW
April	29·77	·11	84	92	78	97	71	70	4·1	1·3	2	2·6	3	ENE	NW
May	29·74	·10	83	91	79	96	63	73	6·0	6·2	7	14·2	3	Var.	NW
June	29·71	·07	79	85	75	93	68	87	8·4	36·8	25	9·9	3	Var.	W
July	29·72	·07	78	84	74	90	68	89	8·7	37·1	27	10·6	3	W	W
August	29·75	·08	77	84	74	90	68	89	8·3	22·5	25	8·1	3	WNW	NW
September	29·78	·10	78	84	74	89	68	87	7·3	10·4	15	7·3	2	ENE	NW
October	29·79	·11	79	86	74	94	67	83	5·6	7·5	10	7·1	3	E	NW
November	29·82	·11	79	88	73	95	60	77	3·8	3·1	5	3·2	3	E	NW
December	29·85	·11	76	89	70	96	60	67	2·5	0·5	0·7	3·2	3	E	NW
Means	29·79	·10	79	87	74	..	..	78	5·1	..	..	..	3	..	..
Totals	..	..	..	..	..	..	..	..	..	125·7	117	..	..	..	..
Extreme values ..	..	..	..	..	..	100	60	..	..	..	..	14·2	..	..	..
No. of years of observations.	32	..	32	11	11	41	41	11	32	42	42	42	41	20	2

* Based on data for 2 years (1938-39).

Cochin.—Lat. 9° 58′ N. Long. 76° 14′ E. Height above M. S. L. 9 ft.

Table compiled from 20 to 43 years' observations between 1878 and 1920.

Month.	Pressure reduced to 32° F & Lat. 45°.		Air temperature.					Relative humidity.	Cloud.	Rain.			Wind.		
	Mean.		Mean. 8 hrs.	Mean daily.		Extreme.				Mean monthly total.	Mean number of days.	Maximum in 24 hours.	Mean daily velocity in miles per hour.	Most frequent direction.	
	8 hrs.	Daily range.	Dry bulb.	Max.	Min.	Max.	Min.	Mean.	8 hrs.					8 hrs.	17 hrs. I.S.T.*
	in.	in.	°F	°F	°F	°F	°F	%		in.		in.			
January	29·92	·13	75	89	72	96	61	72	1·8	0·7	0·9	2·6	4	ENE	W
February	29·91	·14	78	90	74	99	65	75	1·7	0·8	1	4·1	5	ENE	WNW
March	29·88	·14	82	91	77	98	71	76	2·1	2·0	3	3·6	5	ENE	WNW
April	29·83	·12	83	92	79	97	71	76	4·1	4·7	6	5·1	5	ENE	WNW
May	29·81	·10	83	90	78	99	67	80	5·7	11·7	12	6·0	5	ENE	NW
June	29·80	·08	79	85	75	94	66	86	7·7	28·5	24	7·3	5	Var.	WNW
July	29·82	·08	78	84	74	90	68	87	8·0	22·8	24	8·4	5	Var.	WNW
August	29·84	·09	78	84	75	90	68	86	7·3	12·9	18	5·5	5	Var.	WNW
September	29·85	·10	79	85	75	91	70	85	6·2	9·0	14	3·8	4	ENE	NW
October	29·86	·11	79	87	75	92	69	83	5·6	13·2	14	9·3	4	ENE	WNW
November	29·88	·11	79	88	75	94	68	81	4·3	6·5	9	4·8	3	ENE	W
December	29·90	·11	77	89	73	95	64	74	2·9	1·7	3	4·1	3	ENE	W
Means	29·86	·11	79	88	75	..	.	80	4·8	..	..	..	5	..	..
Totals	..	..	..	..	..	..	..	..	..	114·6	129	..	..	..	..
Extreme values ..	..	..	..	..	..	99	61	..	..	..	..	9·3	..	..	..
No. of years of observations.	32	..	32	43	43	43	43	32	32	43	43	43	30	20	2

* Based on data 2 years (1938–39).

Colombo.—Lat. 6° 55′ N. Long. 79° 53′ E. Height above M. S. L. 24 ft.

Table compiled from 30 to 51 years' observations between 1869 and 1920.

Month.	Pressure reduced to 32° F & Lat. 45°		Air temperature.					Relative humidity.	Cloud.	Rain.			Wind.		
	Mean.		Mean 7 hrs.	Mean daily.		Extreme.				Mean monthly total.	Mean number of days.	Maximum in 24 hours.	Mean daily velocity in miles per hour.	Most frequent direction	
	7 hrs.	Daily range.	Dry bulb.	Max.	Min.	Max.	Min.	Mean.	7 hrs.					7 hrs.	17 hrs. I.S.T.*
	in.	in.	°F	°F	°F	°F	°F	%		in.		in.			
January	29·89	·12	76	87	72	94	61	83	4·7	3·4	5	4·7	6	NE	NNW
February	29·88	·13	77	89	72	97	63	83	4·2	2·1	3	2·9	4	NE	WNW
March	29·86	·13	79	90	75	97	69	84	4·3	4·4	6	5·2	4	NE	W
April	29·82	·12	81	89	76	97	69	86	5·7	9·4	11	8·7	4	Var.	WSW
May	29·80	·09	82	88	78	100	63	85	7·1	11·6	13	7·9	6	SW	SW
June	29·79	·08	81	86	77	91	65	85	7·8	7·9	13	6·1	7	SW	SW
July	29·80	·08	80	86	77	89	71	85	7·4	5·1	8	11·6	6	SW	SW
August	29·82	·09	80	86	77	97	70	84	7·1	3·3	6	4·1	6	SW	SW
September	29·84	·11	80	86	77	91	69	84	7·0	4·9	8	7·1	6	SW	SW
October	29·85	·11	79	86	75	93	71	86	6·9	14·1	16	7·3	5	SW	WSW
November	29·86	·11	78	86	74	93	64	86	6·1	12·3	13	7·0	4	NE	W
December	29·87	·12	77	87	73	93	63	85	5·3	5·5	7	6·4	6	NNE	NNW
Means	29·84	·11	79	87	75	..	..	85	6·1	..	..	..	5		..
Totals	..	..	..	..	..	..	..	..	..	84·2	111	..	..		
Extreme values ..	..	..	..	..	..	100	61	..	..	..	..	11·6	..	Not	..
													..	avail-	..
No. of years of observations.	32	.	32	32	32	43	43	30	30	43	43	42	51	able.	2

* Based on data for 2 years (1938-39).

Madras.—Lat. 13°4′6″ N. Long. 80°14′54″ E. Height above M.S.L. 22 ft.

Table compiled from 12 to 51 years' observations between 1870 and 1920.

Month.	Pressure reduced to 32° F & Lat. 45°.		Air temperature.					Relative humidity.	Cloud.	Rain.			Wind.		
	Mean.		Mean. 8 hrs.	Mean daily.		Extreme.				Mean monthly total.	Mean number of days.	Maximum in 24 hours.	Mean daily velocity in miles per hour.	Most frequent direction.	
	8 hrs.	Daily range.	Dry bulb.	Max.	Min.	Max.	Min.	Mean.	8 hrs.					8 hrs.	17 hrs. I.S.T.*
	in.	in.	°F	°F	°F	°F	°F	%		in.		in.			
January	29·97	·11	74	85	68	93	57	84	3·4	1·4	2	8·4	4	NW	NE
February	29·93	·12	76	87	69	96	60	83	2·5	0·3	0·6	2·5	4	W	ESE
March	29·88	·13	80	90	72	102	62	79	2·2	0·2	0·3	2·0	4	SW	SE
April	29·81	·13	85	93	77	109	69	75	4·0	0·5	0·7	3·3	5	SSW	SE
May	29·71	·12	88	99	81	113	70	66	3·8	1·1	1	5·2	6	SSW	SE
June	29·67	·12	87	99	81	110	69	62	5·7	1·9	4	2·1	6	WSW	SE
July	29·68	·12	84	96	79	106	71	70	6·9	3·9	7	4·6	5	WSW	SE
August	29·72	·12	83	94	78	104	69	75	6·6	4·6	8	2·9	5	WSW	SE
September	29·75	·13	82	93	77	102	69	78	6·2	5·0	7	3·9	4	WSW	SE
October	29·82	·12	81	89	75	103	62	83	5·2	11·7	11	9·2	3	W	E
November	29·89	·11	78	85	73	95	59	84	5·5	14·3	11	8·2	5	Var.	NE
December	29·95	·11	75	83	70	95	57	83	4·7	5·8	5	10·3	5	NW	NE
Means	29·81	·12	81	91	75	..	..	77	4·7	..	..	..	5	..	..
Totals	..	..	..	..	..	..	..	..	..	50·8	57	..	..	..	..
Extreme values ..	..	..	..	..	..	113	57	..	..	..	..	10·3	..	..	..
No. of years of observations.	32	..	32	43	43	43	43	32	32	43	43	43	51	~~12~~ 5	7

* Based on data for 7 years (1933—39).

Vizagapatam.—Lat. 17°42′ N. Long 83°18′ E. Height above M. S. L. 38 ft.

Table compiled from 12 to 48 years' observations between 1872 and 1920.

Month.	Pressure reduced to 32° F & Lat. 45°.		Air temperature.					Relative humidity.	Cloud.	Rain.			Wind.		
	Mean.		Mean 8 hrs.	Mean daily.		Extreme.				Mean monthly total.	Mean number of days.	Maximum in 24 hours.	Mean daily velocity in miles per hour.	Most frequent direction.	
	8 hrs.	Daily range.	Dry bulb.	Max.	Min.	Max.	Min.	Mean.	8 hrs.					8 hrs.	17 hrs. I.S.T.*
	in.	in.	°F	°F	°F	°F	°F	%		in.		in.			
January	29·98	·12	72	81	68	90	60	72	2·7	0·5	0·5	5·2	3	NW	ENE
February	29·92	·13	75	84	71	91	61	73	2·9	0·9	0·9	2·5	3	W	SSW
March	29·86	·13	80	87	75	97	66	73	2·9	0·5	0·5	1·7	4	W	SSW
April	29·78	·13	84	90	78	99	68	71	4·3	0·7	2	2·7	5	WSW	SW
May	29·67	·12	87	92	81	110	68	71	5·7	2·0	3	8·3	5	WSW	SW
June	29·56	·10	85	91	80	111	70	74	7·8	4·9	7	5·9	4	WSW	SW
July	29·55	·09	83	89	79	101	71	78	8·3	4·5	8	5·3	4	W	WSW
August	29·59	·11	82	89	78	99	70	87	7·9	5·4	8	4·0	4	W	SW
September	29·67	·11	83	88	78	98	72	79	7·1	6·5	9	10·8	3	W	SW
October	29·80	·11	81	88	76	96	69	74	5·1	7·1	7	8·7	3	Var.	Var.
November	29·90	·11	77	84	73	91	61	65	4·4	3·7	4	5·8	3	Var.	ENE
December	29·97	·12	73	81	68	88	60	63	3·3	0·7	1	10·3	3	NNW	E
Means	29·77	·11	80	87	75	.	..	73	5·2	..	..	..	4	..	..
Totals	..	.	.	.	.	..	..	..	..	37·1	51	..	.	..	..
Extreme values	..	.	..	..	.	111	60	..	..	.	..	10·8	..	..	..
No. of years of observations.	32		32	25	25	24	24	25	32	24	24	43	48	~~12~~ 5	7

* Based on data for 7 years (1933—39).

Calcutta.—Lat. 22° 32′ N. Long. 88° 20′ E. Height above M.S.L. 21 ft.

Table compiled from 27 to 45 years' observations between 1875 and 1920.

Month.	Pressure reduced to 32° F & Lat. 45°.		Air temperature.					Relative humidity.	Cloud.	Rain.			Wind.		
	Mean.		Mean. 8 hrs.	Mean daily.		Extreme.				Mean monthly total.	Mean number of days.	Maximum in 24 hours.	Mean daily velocity in miles per hour.	Most frequent direction.	
	8 hrs.	Daily range.	Dry bulb.	Max.	Min.	Max.	Min.	Mean.	8 hrs.					8 hrs.	17 hrs. I.S.T.*
	in.	n.	°F	°F	°F	°F	°F	%		in.		in.			
January	30·01	·13	60	77	56	88	44	85	2·0	0·3	0·7	1·7	2	Var.	NNW
February	29·95	·13	63	82	60	93	46	82	2·6	1·1	2	3·2	3	Var.	NW
March	29·85	·13	75	91	69	103	50	80	2·9	1·4	2	2·7	4	SW	SSW
April	29·75	·13	82	95	76	107	61	79	3·6	1·9	3	4·2	5	SW	SSW
May	29·66	·12	84	95	78	107	65	79	4·7	5·7	7	6·1	5	SSW	SSW
June	29·53	·09	83	91	79	108	70	85	7·4	11·9	13	11·9	4	SSW	S
July	29·51	·09	82	89	79	98	68	88	8·6	12·5	18	7·2	4	S	S
August	29·56	·09	82	88	79	94	74	89	8·5	12·7	18	10·0	3	S	SSW
September	29·68	·11	82	88	78	95	72	87	6·9	9·9	13	14·5	3	S	S
October	29·83	·11	79	87	75	94	63	85	3·6	4·2	6	6·8	2	N	Var.
November	29·95	·11	70	82	65	91	51	82	2·0	0·7	1	3·2	2	NNW	NNW
December	30·02	·13	61	77	56	85	45	81	1·5	0·2	0·4	2·1	2	N	NNW
Means	29·77	·11	75	87	71	..	..	83	4·5	..	..	..	3	..	..
Totals	..	..	..	..	..	..	..	..	..	62·6	85	..	..	..	..
Extreme values	..	..	..	..	..	108	44	..	..	..	..	14·5	..	..	..
No. of years of observations.	32	..	32	43	43	43	43	32	32	43	43	43	45	~~37~~ 5	7

* Based on data for 7 years (1933—39).

Akyab.—Lat. 20° 8′ N. Long 92° 55′ E. Height above M.S.L. 20 ft.

Table compiled from 12 to 48 years' observations between 1872 and 1920.

Month.	Pressure reduced to 32° F & Lat. 45°.		Air temperature.					Relative humidity.	Cloud.	Rain.			Wind.		
	Mean.		Mean 8 hrs.	Mean daily.		Extreme.				Mean monthly total.	Mean number of days.	Maximum in 24 hours.	Mean daily velocity in miles per hour.	Most frequent direction.	
	8 hrs.	Daily range.	Dry bulb.	Max.	Min.	Max.	Min.	Mean.	8 hrs.					8 hrs.	17hrs. I.S.T.*
	in.	in.	°F	°F	°F	°F	°F	%		in.		in.			
January	29·97	·11	63	81	59	91	47	88	1·5	0·1	0·1	1·0	2	NNE	WNW
February	29·93	·12	66	84	61	95	49	83	1·5	0·1	0·4	0·9	3	NNE	W
March	29·88	·12	74	89	69	100	54	83	2·7	0·5	0·7	2·8	3	NNE	W
April	29·82	·12	81	91	75	99	62	81	4·1	2·1	2	11·5	3	NE	W
May	29·73	·11	83	91	78	99	66	84	5·9	13·9	11	11·4	3	ENE	WSW
June	29·63	·09	81	86	77	98	68	92	8·4	46·9	24	15·0	3	SE	S
July	29·62	·08	80	85	77	93	71	94	8·8	54·8	28	13·5	3	SE	S
August	29·66	·09	79	85	77	91	71	94	8·7	45·2	27	15·9	3	Var.	SSW
September	29·73	·11	80	86	77	94	70	93	7·3	22·6	19	9·7	2	ENE	S
October	29·84	·11	79	87	76	99	65	91	5·4	10·9	9	10·3	2	NE	W
November	29·91	·11	73	85	71	92	59	90	3·7	5·5	4	18·3	2	NNE	WNW
December	29·96	·11	66	81	63	90	51	90	2·3	0·8	0·9	5·3	2	NNE	WNW
Means .. .	29·81	·11	75	86	72	..	..	89	5·0	..	..	..	3	..	..
Totals .. .	..	..	..	..	..	..	..	..	..	203·4	125	..	..	..	..
Extreme values .	..	..	..	..	..	100	47	..	..	..	..	18·3	..	..	..
No. of years of observations.	32	..	32	43	42	43	43	32	32	43	43	43	48	~~12~~ 5	7

* Based on data for 7 years (1933—39).

Rangoon.—Lat. 16°46′N. Long 96°11′E. Height above M.S.L. 18 ft.

Table compiled from 24 to 43 years observations between 1878 and 1920.

Month.	Pressure reduced to 32° F & Lat. 45°.		Air temperature.					Relative humidity.	Cloud.	Rain.			Wind.		
	Mean.		Mean. 8 hrs.	Mean daily.		Extreme.				Mean monthly total.	Mean number of days.	Maximum in 24 hours.	Mean daily velocity in miles per hour.	Most frequent direction.	
	8 hrs.	Daily range.	Dry bulb.	Max.	Min.	Max.	Min.	Mean.	8 hrs.					8 hrs.	17 hrs. I.S.T.*
	in.	in.	°F	°F	°F	°F	°F	%		in.		in.			
January	29·95	·13	69	89	65	97	55	82	3 0	0·2	0·3	2·9	3	NNE	Var.
February	29·91	·14	70	92	67	100	56	84	2·8	0·2	0·3	1·9	3	NNE	S
March	29·87	·15	75	96	71	103	61	85	3·6	0·3	0·6	1·6	3	Var.	S
April	29·83	·15	81	98	76	106	68	80	4·1	1·6	2	5·0	4	WSW	S
May	29·76	·12	81	92	77	105	71	86	7·3	12·0	14	9·1	3	SW	S
June	29·71	·09	80	86	76	98	71	91	8·9	18·0	23	5·4	4	S	SSW
July	29·71	·08	79	85	76	93	72	92	9·2	21·4	25	5·1	4	SSW	SSW
August	29·73	·09	79	85	76	92	68	93	9·1	19·9	24	5·3	3	SSW	SSW
September	29·78	·11	79	86	76	94	72	92	8·6	15·3	20	5·2	3	SSW	SSW
October	29·85	·12	79	88	76	94	70	90	6·5	6·9	10	5·3	2	NNE	S
November	29·91	·11	76	87	73	94	61	86	4·5	2·8	3	10·4	3	NNE	Var.
December	29·95	·12	71	87	67	98	57	82	3·4	0·4	0·6	4·0	3	NNE	Var.
Means	29·83	·12	76	89	73	..	..	87	5·9	..	..	..	3	..	..
Totals	..	..	..	..	..	..	..	..	..	99·0	122	..	..	..	..
Extreme values ..	..	..	..	..	..	106	55	..	..	..	..	10·4	..	..	..
No. of years of observations.	32	..	32	43	43	43	43	32	32	43	43	43	42	24 5	7

* Based on data for 7 years (1933—39).

Victoria Point.—Lat. 9° 59′ N. Long. 98° 35′E. Height above M.S.L. 147 ft.

Table compiled from 9 to 11 years' observations between 1910 and 1920.

Month.	Pressure reduced to 32° F & Lat. 45°.		Air temperature.					Relative humidity.	Cloud.	Rain.			Wind.		
	Mean.		Mean 8 hrs.	Mean daily.		Extreme.				Mean monthly total.	Mean number of days.	Maximum in 24 hours.	Mean daily velocity in miles per hour.	Most frequent direction.	
	8 hrs.	Daily range.	Dry bulb.	Max.	Min.	Max.	Min.	Mean.	8 hrs.					8 hrs.	17 hrs. L.S.T.*
	in.	in.	°F	°F	°F	°F	°F	%		in.		in.			
January	29·79	..	77	86	73	93	65	76	4·0	0·3	0·8	0·5	6	NE	ENE
February	29·76	..	78	89	74	97	67	77	3·6	0·1	0·3	0·7	6	NE	NW
March	29·74	..	80	90	76	97	71	79	4·6	1·3	2	1·9	6	NE	NW
April	29·71	..	82	90	77	99	70	81	5·6	3·9	7	3·1	5	ENE	NW
May	29·67	..	81	87	76	105	71	85	6·8	17·1	19	6·0	5	Var.	SW
June	29·66	..	80	85	75	90	71	87	7·6	28·3	22	5·9	6	SW	SW
July	29·66	..	79	83	75	89	70	88	7·7	30·0	23	6·9	7	SW	SW
August	29·67	..	79	83	75	88	70	88	7·4	25·5	22	5·7	6	SW	SW
September	29·69	..	78	83	74	89	69	88	7·3	25·9	22	5·7	5	Var.	SW
October	29·73	..	79	84	74	90	71	87	6·7	18·0	19	5·0	4	ENE	Var
November	29·73	..	79	85	75	95	68	82	5·9	5·8	11	3·8	5	NE	NE
December	29·75	..	77	85	73	91	64	78	5·5	2·7	5	4·7	5	NE	NE
Means	29·71	..	79	86	75	..	..	83	6·1	..	..	..	5	..	..
Totals	..	..	..	..	..	..	..	..	..	158·9	151	..	..	..	..
Extreme values ..	..	..	..	..	..	105	64	..	..	..	..	6·9	..	..	..
No. of years of observations.	11	..	10	10	10	10	10	10	10	10	10	10	9	~~11~~ 5	6

* Based on data for 6 years (1933—38).

APPENDIX III.

Alphabetical Glossary of some important meteorological terms occurring in "Winds, Weather and Currents".

Anti-cyclone.—A type of atmospheric circulation with high pressure at the centre. The winds blow *out of* and around the centre; clockwise in the northern hemisphere and counter-clockwise in the southern hemisphere. The winds are usually moderate or light and fine weather prevails.

Atmosphere.—The ocean of air surrounding the earth.

Backing of wind.—The changing of wind in a counter-clockwise direction, *i.e.*, N→W→S→E. Opposite of 'veering.'

Barometer.—An instrument for measuring the pressure of the atmosphere.

Beaufort scale.—A scale for estimating the force of wind by its effects at sea or on land consisting of 13 figures, 0 (calm) to 12 (hurricane) and devised by Admiral Beaufort. *See chapter I.*

Bore.—On entering some river-mouths or gulfs, the tidal current takes the form of a tidal wave of great volume which travels up-stream. When the time of high tide coincides with the passage of a cyclonic storm inland, the tidal wave may be exceptionally high and cause great damage.

Buys Ballot's Law.—Rules which indicate the position of low pressure areas with respect to wind direction. "Face the wind and the low pressure will be to your right hand in the northern hemisphere. In the southern hemisphere, the reverse will be true."

This law can also be stated in the form that in the northern hemisphere, winds go counter-clockwise around lowpressure centres and clockwise around highpressure centres, the reverse holding true in the southern hemisphere.

Current.—A general movement of a permanent or semi-permanent nature of the surface waters of the ocean. The term must not be used to denote tidal movements which change their direction and speed hour by hour. The set of the current is the direction *towards* which it flows, *not the direction from* which it comes, as in the case of wind. The drift of the current is the rate at which it flows.

Cyclone.—A type of atmospheric circulation with low pressure at the centre. The winds blow *into* and around the centre; counter-clockwise in the northern hemisphere and clockwise in the southern hemisphere The weather is usually cloudy, overcast and rainy with boisterous, squally winds.

Depression.—The term " depression " is limited to those circulations round a low pressure area in which the maximum wind speed does not reach the strength of a gale, *i.e.*, is of force 7 or less on the Beaufort scale. According to a convention of the India Meteorological Department, the " depression " becomes a " storm " when the wind in any part of the disturbed area rises to gale force (force 8); when it rises to force 10, with occasional hurricane squalls, the storm is said to be " severe ".

Fog.—Extremely small droplets of condensed moisture suspended in the atmosphere and of such density that objects beyond 1,100 yards cannot be distinguished. During fog the wind is usually light or calm and the relative humidity at least 75%. If the maximum visual range is between 1,100 yards and 1¼ miles and the relative humidity at least 75%, the obscurity is called *mist.* When the obscuration is caused by foreign solid particles such as dust or smoke, it is called *haze.*

Gale.—A wind of force 8 to 11 on the Beaufort scale. The corresponding range of wind speed is 34 to 65 miles per hour.

Haze.—See under fog.

Hurricane winds.—Winds of force 12 on the Beaufort scale. The corresponding wind speed is above 65 miles per hour.

Isobars.—A line passing through points having the same pressure.

Land and sea breezes.—Coastal winds caused by the unequal heating and cooling of land and sea under the influence of solar radiation by day and radiation to the sky at night, which produce a gradient of pressure near the coast. During the day when the land is warmer than the sea, a breeze from the sea blows on shore, while at night and in the early morning when the land is cooler than the sea the land breeze blows off shore. These breezes are best developed when the general pressure gradient is slight and the skies are clear. In such circumstances, the sea breeze usually sets in at about noon and continues till the early part of the night, reaching its maximum strength during the afternoon; the land breeze usually begins some time in the latter half of the night and continues till 8 or 9 hours in the morning.

Mist.—See under fog.

Monsoons.—Large-scale seasonal winds between extensive land areas and neighbouring seas. The winds flow landward in summer and seaward in winter. The southwest and northeast winds of India are the biggest monsoon system in the world.

Nor'westers.—During the hot season (March to May) Bengal and Orissa are occasionally visited by a type of severe thunderstorms known

as *Nor'westers*. They are locally described as Kal-Baisakhi. These storms usually approach a station from NW and burst suddenly with great fury, raising clouds of dust.

Shamals.—Winds from the northwest which blow behind western disturbances during the period December to April in the Persian Gulf and the Mekran. The strong northwesterly winds which often blow in summer are also called by the local residents by this name.

Squall.—A strong wind that rises suddenly to a strength of 25 miles per hour or more, lasts for some minutes and dies down again comparatively quickly. This may be repeated a number of times.

Squalls are to be distinguished from gusts, which are the rapid fluctuations of wind generally caused by local obstructions and surface friction.

Storm.—The term 'storm' is a general term used for any violent atmospheric commotion, for example, thunderstorm, line-squall, rain storm, duststorm or snow storm (see also depression).

Storm warning signals.—Whenever a storm or disturbance exists in the Indian Seas, suitable visual warnings are hoisted at such ports on the coasts as are likely to be affected by the disturbance (see chapter VIII).

Swell.—Long waves generally caused by wind at a distance from the place of observation.

Thunderstorm.—Strong electrical discharges in the atmosphere caused by powerful rising currents within fully developed cumulonimbus clouds. Thunderstorms are often accompanied by squalls and heavy rain.

Tide.—The daily and fortnightly rise and fall in level of the sea caused by the attraction of the moon and the sun.

Tidal wave.—At the time of high tide, water often rushes into indentations on the coast in the form of a large wave.

Veering of wind.—The changing of wind in a clockwise direction, i.e., N→E→S →W. Opposite of 'backing'.

Vertex or cod of a storm.—The turn in the line of progression of a tropical cyclone where the path of the storm changes from a westerly to an easterly direction.

Visibility.—The maximum distance at which objects of sufficient size such as trees, buildings, etc., can be seen and identified by the unaided eye.

Vortex or Eye of a storm.—The central calm area of a cyclonic storm within the ring of hurricane winds round it, where the barometer is lowest.

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